Timber City proposes a radical pivot from the construction practices that have dominated North American cities for over a century: instead of utilizing steel or concrete, the architecture of the future city might be harvested from trees.

Mass timber structural systems, and the sustainable forestry practices and material science that support them, promise a new synergy between dense cities, healthy forests, and a thriving industrial economy based in wood.

The building and infrastructural demands of a rapidly urbanizing global population offer an opportunity to dramatically reduce the carbon footprint of the building sector. Timber City provides a “cradle to gate” instruction manual for transforming the 21st century city from CO2 source to carbon sink.
The contemporary city is composed of high-reaching, long-spanning, heavy-load-bearing urban artifacts constructed from iron, steel, and concrete. These materials were smelted, sintered, and synthesized from raw ingredients extracted from ever-deeper geologies.

The very way we construct our environment, currently a significant source of overall anthropogenic greenhouse gas emissions, might instead become a means to offset them. This argument is supported by recent research on building life cycle impacts and forest-carbon management, bolstered by rapid breakthroughs in mass timber engineering and production technology, and made all the more pressing by mounting evidence of rapidly accelerating global climate change.
GLOBAL MATERIAL CONSUMPTION

The trajectory of a rapidly urbanizing global population has created an asymmetrical growth pattern: developed countries have remained relatively stable in terms of population and resource consumption, while developing countries have exhibited exponential growth in both their appetite for resources and their growing populations which consume those materials. In contrast, to relatively stable population growth and consumption patterns for members of the Organisation for Economic Co-operation and Development (OECD), the metrics for Brazil, Russia, India, China, and South Africa (BRICS), have exhibited a rapid acceleration in demand over the past 30 years, from 2.75 metric tons per capita in 1980 to 9.75 metric tons in 2010.

While the volumetric change in total resource needs reflects larger social and economic shifts underway in the BRICS counties, a more dramatic shift in consumption patterns is evident in the ratios of material use. In 1980, the demand for construction materials (glass, concrete, gravel, and sand) was approximately twice that of wood products. However, by 2010 the demand for concrete had risen by 600% while the demand for wood actually declined slightly.

CARBON IMPLICATIONS

This pattern of developing nations abandoning timber construction in favor of concrete structures has massive implications for extractive industries and carbon emissions. Concrete and steel have much higher embodied energy emissions than wood, rely on damaging extractive processes, and they lack timber’s capacity to sequester carbon. Timber City proposes models of urban growth that can accommodate new populations while limiting carbon emissions.
Our current culture of land use and resource allocation—and the regulatory systems that reinforce it—has relegated contemporary use of structural timber to the commercially profitable but relatively modest structural demands of light-framed, low-rise, low-density applications in the residential building sector.

On a continent as timber rich as North America, it is both a conceptual irony and a significant environmental risk that this renewable material, with demonstrably low extraction, processing, and production impacts and energy demands, has produced the land- and energy-intensive sprawl of suburbia, one of the United States’ most durable and pervasive global exports. Meanwhile, the materially demanding building morphologies of our cities, with their relatively efficient use of surface area, space, and infrastructure, are generated from a class of structural materials with a large carbon footprint.
GLOBAL POPULATION DEMANDS

According to projections from the United Nations, the global population will reach 9.7 billion people by 2050. 2007 marked the first time in history that the majority of the world’s population lived in cities rather than rural areas, and the majority of population growth will continue to occur in the world’s urban regions. By 2050, 65% of the world will live in cities.

For the majority of the 20th century, urban populations were overwhelmingly located in developed countries, while less developed countries were primarily composed of rural populations. The United Nations predicts that by 2050, the urban areas of less developed nations will host a higher number of urban dwellers than those in developed countries. In these future developing cities, building solutions will need to be cost-effective, durable, sustainable and reliant on flexible, readily-deployed, low-cost infrastructures. Furthermore, the very patterns of urban development which defined the 20th century—namely the single family house and the resulting trend of low density suburbia—will need to transition towards higher density and lower carbon impacts than their predecessors.

AN URBAN FUTURE

In the 21st century, cities will not only house the majority of the world’s population, but will become epicenters of new construction, resource consumption, and carbon emissions. If built from wood rather than concrete and steel, the vast number of buildings required to satiate the world’s tenuous demand for housing may offer the means to establish a sustainable development model for the future.
Mass timber, previously underutilized in the heavy-load-bearing structures associated with urban dwelling and the cityscape, might now be embedded in parking garages, bridges and overpasses, commercial buildings, and industrial facilities storing carbon reserves in a symbiotic offset of the carbon emitted by the drivers and cars that use them.

Carbon becomes a structural asset, the forest its growth engine, the dense urban center its parsimonious bank.
**OPPORTUNITY FOR A BETTER URBANISM**

As a brief thought experiment, consider the savings that would accrue to reconfiguring the structural components of what was once central to the American Dream: the studs, joists, rafters, plywood sheathing, and subfloors of an average 2,400-square-foot, single-family suburban house. If the wood fiber contained in the 38,000 board feet (30 metric tons) of light sticks and thin veneers that form the skeletal system of suburbia were instead laid up as dense, structurally efficient glue-laminated assemblies to produce equivalently sized, similarly programmed units of mid-rise urban housing, we would shift approximately 1,500 households onto an area of land that would have held only about thirty families in their freestanding wood-framed suburban houses.

As the density of construction and habitation increases, the costs of producing better performing building envelopes and mechanical systems decreases, as many more inhabitants are bearing the costs. This relieves the individual homeowner of the increasingly onerous demands of owning and maintaining a free-standing home and the demands placed on municipal infrastructure.

Mass timber, previously underutilized in the heavy-load-bearing structures associated with urban dwelling and the cityscape, might now be embedded throughout the city, storing carbon reserves in a symbiotic offset of the carbon emitted by the drivers and cars that use them. Transitioning from suburban sprawl to higher density urbanism not only concentrates dwellings into increasingly efficient footprints, but frees the landscape of its burdensome, low-density population. Unencumbered by impermeable soil cover, and with its biological and hydrological systems increasingly intact, the landscape would become a biomass producer and high-functioning collector of CO2. In a Timber City, carbon is a structural asset, the dense urban center its parsimonious bank.

**Typical suburban neighborhood compared to a high-density mid-rise neighborhood**

<table>
<thead>
<tr>
<th>Building Footprint</th>
<th>Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>575x575'</td>
<td>1,582</td>
</tr>
<tr>
<td>1050x520'</td>
<td>28.5</td>
</tr>
</tbody>
</table>

In comparing the relative carbon impacts of constructing a typical mid-rise commercial project with concrete and steel vs mass timber, a timber building offers the opportunity to avoid significant carbon emissions (66 teratons), while a similar concrete building is a net emitter of carbon during its construction (40 teratons). The net differential exceeds 100 teratons, roughly equivalent to saving 11,500 barrels of oil.

On average, a single family home constructed with conventional framing methods will only sequester 10 kilograms of carbon per square foot. By increasing the single family home’s construction to mass timber, the sequestration potential increases 155%, while multi-family mass timber offers 332% the sequestration potential of typical suburban homes.
NEW MASS TIMBER TECTONICS

It is perhaps wood's natural heterogeneity, the unpredictable defects of the raw material, and the variation in the properties, processing requirements, and performance characteristics of the fiber (depending on species and growing region) that have been timber's greatest disadvantage in the marketplace of high-strength structural products. The varying properties of different species drawn from the same forest and even the differing structural capacity of timber sawn from the same tree have been a disincentive to a building industry seeking economies of scale, repetitive manufacturing procedures, and homogenous raw material. But analytical protocols and industrial practices that are already in place at a basic level in mass timber manufacturing may provide the seeds for a more tolerant and holistic use of the structural materials available in the forest.

Digital analysts and material optimization systems that are increasingly industry standards can produce enormous efficiencies in the use of the trees we cut. They also create the potential for a more comprehensive approach to our forests as a renewable resource, optimizing the use of a range of species with lower structural values that in turn enables us to manage forest stands in ways that better emulate natural growth. The sorting, grading, and re-sawing, the removal of flaws (unsound knots or checks), and the subsequent finger-jointing of small boards into longer, structurally improved sticks allow the strongest and highest-quality material found in a tree to be positioned where it can do the most structural work.

By developing an array of structural products and assemblies that seek to exploit existing techniques in mass timber production—and to utilize a greater diversity of plant fiber growing naturally in our forests—we can promote healthy biocultural diversity while fixing increasing amounts of carbon in the structural products we specify. Recent experimentation anticipates the broader use of mixed-species layups; these distribute woods with different properties within customized configurations designed for varying structural demands and applications. New products already under development include hybridized structural members and assemblies that take advantage of the lightness, appearance, renewability, or tensile strength of timber while introducing small, optimally configured amounts of glass and carbon fiber, steel, or reinforced concrete to magnify performance.

Today, our use of structural timber is limited to a narrow spectrum of commercially familiar species and grades of solid lumber. The processes inherent in mass timber technologies might offer a promising means to broaden our use of this abundant resource. In the United States, we have only begun to develop new mass timber systems as commercial products; teach their principles, means, methods, and potentialities in our design and engineering schools; measure and articulate their environmental benefits; and adopt their solutions in the professional arena.
The challenge today is a system-wide accounting that seeks to balance the potential productivity of forest ecologies in relation to the material and energy demands of the construction sector.

This accounting anticipates inevitably massive investment in the material and technology required to house shifting populations in necessarily better-performing building envelopes. It assigns value to an economic symbiosis found in forest supply and construction demand which has both environmental implications and immediate application around the globe.
timber city: a case study

The Timber City implementation model seeks to marshal expertise from the fields of forestry and silviculture, material science and industrial mass timber production, architectural design and engineering in an effort to address the concerns and objectives of land use administrators, urban regulators, and property developers facing simultaneous projections of decreasing forest resiliency and significant urban growth. Spanning the building life cycle from “cradle to gate”—from sustainable forest management to the development and construction of replicable urban building types in timber—the model proposes the formation of a robust yet financially feasible architectural and structural urban building typology in timber and the means, methods, and probable impacts of producing them.

The case study site is a center city block in the vibrant post-industrial city of New Haven, Connecticut. The forests which will serve as its material source lie a few hundred miles to the north in Vermont, New Hampshire, and Maine. Replication sites and forest sources are currently under review in Turkey, Ecuador, Japan, and Australia.
** CASE STUDY PROPOSAL 

The city of New Haven serves as the site for the first Timber City case study. Situated along the southern coastline of New England, New Haven is a prototypical urban condition for the entire Northeast United States. One of the first planned cities in North America, New Haven was founded on a large harbor of the Long Island Sound. Two major interstates and three commuter rail lines arrived during the mid-twentieth century, connecting New Haven to the increasingly dense Northeast Corridor.

With the arrival of new transportation infrastructure, New Haven experienced a growing pain familiar to many cities in the region: disinvestment and demolition of historic building stock. The most dramatic change to New Haven’s urban fabric is visible in the downtown core. Originally developed as a nine square plan, over time these parcels have been subdivided into smaller city blocks. As the city’s population shifted from downtown and towards the suburbs, the density of buildings in the 9 squares also began to decrease.

Today, however, New Haven is in the midst of an urban resurgence. The New Haven City and Town area (NECTA) ranks as the 6th most populous urban area in New England with a population of 99,772 residents. Between 2000 and 2010, New Haven experienced the highest population growth rate of any city in the Northeast. In response, Mayor Toni Harp and her administration have publicly supported plans to bring 10,000 mixed-income residential units into the city over the next decade. As the city continues to grow and densify, the downtown core will be a primary site for new construction.

The distribution of property ownership in New Haven is heavily skewed towards municipal and academic entities. Furthermore, the majority of these properties are concentrated in the downtown core, an area that will be in high demand for residential and mixed-use construction in the upcoming decade.

The population of New Haven and its surrounding towns is poised to increase by 15,000 residents in the next decade. Most of this growth will be in New Haven.

The city’s downtown core was designed as a nine-square grid. Currently, this area comprises downtown, Yale University, and the public Green. Highlighted lots indicate properties available for timber development.
REGIONAL FOREST DISTRIBUTION

As one of the most densely forested regions of the United States, New England has long been a historic center for the production, export, and consumption of wood products. Specifically, Maine's early economy revolved around the abundant white pine that flourished throughout the state. The lumber economy grew so rapidly during the 19th century that by 1832, Bangor claimed the title as the largest shipping port for lumber in the entire world. Demand for high-quality timber not only transformed New England's colonial economy, but manifested itself within the landscape of the region.

According to researchers at the Harvard Forest, the past 300 years of settlement, industrialization, and urbanization of New England dramatically transformed the natural ecosystems and landscapes of the region. The mid-nineteenth century was particularly dramatic, as the majority of New England was converted from forests to farmland, destroying much of the native timber stocks in favor of pastures, orchards, and villages. However, these artifacts of the agricultural industrial economy were relatively short-lived. As the country continued to expand westward, and as the industrial economy grew from localized production to regional manufacturing, the viability of small New England farms diminished, and the agricultural landscapes were slowly supplanted by new timber growth.

ECONOMIC IMPLICATIONS

Today, New England has a robust and well-developed forest products economy that caters to a diverse array of industries, connects to markets around the world, and produces lumber and pulp in addition to a number of manufactured forest products. These complex supply chains are composed of managed forest lands, transportation routes, processing and manufacturing centers, and urban markets.

According to the Nature Conservancy, New England's forests directly contribute $20 billion to the regional economy through the management and production of forest products. Given this incredibly active and productive forest system, along with the dense urbanization patterns along the Northeast corridor, New England has a unique potential to create a novel paradigm between its cities and its hinterlands. With the remote North Woods of Maine only 400 miles from the megalopolis of Southern Connecticut and New York City, an economic strategy that introduces timber building products into densifying urban centers would produce new, productive, and sustainable models of building.

New England’s forest reserves are concentrated in Maine, New Hampshire, and Vermont, while the majority of its urbanized population lives in Connecticut, Massachusetts, and Rhode Island. The networks of transportation infrastructure required to support the timber industry are primarily located along the Atlantic coastline, and most connect through the Boston and Hartford metropolitan regions.
While New England is heavily forested compared to the majority of the United States, the largest and most heavily forested state in this region is Maine, a state whose forest industry accounts for $6 billion each year, nearly half of New England’s entire forest economy. The majority of the lumber produced in Maine is devoted to the pulp and paper industry, which has historically been an important focus for the regional economy. However, in the past two decades, the paper industry has sold the majority of its land holdings in New England, and more recently has begun to close its mills and factories due to competition from foreign manufacturing. New England’s forest products industry needs to identify alternative economic models that utilize the same softwood lumber stocks previously devoted to pulp and paper.

Examining the composition of Maine’s forests reveals a potential pivot away from manufacturing paper and towards the production of structural mass timber. Maine has an ideal species mixture for the manufacturing of CLT: black spruce, fir, and white pine. Easy to work, quick to grow and with a desirable strength-to-weight ratio, this combination of timber species is commonly referred with the designation SPF. Additionally, reorienting Maine’s forest towards an emerging market may satisfy the timber real estate investment trusts (REIT) and timber investment management organizations (TIMO) which control the majority of privately owned timberland in New England. Displacing vertically-integrated industrial models who saw the forests as raw material, these investment companies see timberland as assets with the ability to create new markets.

MARKET OPPORTUNITIES

Currently, the infrastructure of New England forest industries is oriented towards products and materials that reflect the prevailing consumption pattern of North American suburbs: dimensional lumber, veneer, wood flooring, plywood, MDF, and OSB, in addition to the products offered by the well-established but declining pulp and paper industry. A few companies in the region have established mass timber manufacturing and fabrication capacities—Nordic Structures in Montreal, Unilam in central New York, and Bensonwood Homes in New Hampshire—but these few pioneers account for a minuscule share of New England’s forest products. As the demand for mass timber structures accelerates in urban centers throughout North America, the market for value-added forest products, such as glue-laminated and cross-laminated timber, will grow exponentially and the ability to meet that demand may determine the future health of New England’s forest industries.

The forest products industry is comprised of a wide variety of products and materials, ranging from solid lumber to manufactured composites to highly refined chemical compounds. Within this spectrum, CLT and glulam value-added products that maintain the aesthetic appeal and carbon benefits of timber while offering superior structural performance than other structural lumbers.
VERTICALLY INTEGRATED PRODUCTION

While New England's mass timber industry is still in its infancy, Quebec offers a precedent for creating an efficient, vertically-integrated mass timber production strategy that has direct applications to developing complementary industries in the United States. As the preeminent mass timber manufacturer in North America, Montreal-based Nordic has developed a sophisticated, environmentally conscious industrial model that addresses timber as a natural resource and a value-added product. Their corporation includes Forêt Nordique (forest management and infrastructure development), Chantiers Chibougamau (primary wood processing), Société Landrémont (dimensional lumber production), and Nordic Structures (engineered wood products).

Nordic’s forestry operations consist of over 2 million acres in Northern Quebec, with timberlands rich in black spruce, jack pine, and balsam fir. Critically, the Chantiers Chibougamau processing facility is located in the center of these forest reserves, extending a 175 kilometer harvest radius from the mill. In order to maximize the yield of their forest reserves, Chantiers Chibougamau employs a sophisticated grading and sorting process that enables them to utilize a higher range of harvested timber than traditional processing technologies would allow. The resulting sawn timber is then sorted into its best uses, either as dimensional lumber or as an engineered wood product.

While standard glue-lamination techniques have remained largely unchanged from their original manufacturing principles, advances in mass timber fabrication have enabled manufacturers to construct larger members with more complex geometries at a greater level of precision than previously possible. Achieving these complicated forms and enormous member sizes requires a highly skilled workforce and a sophisticated array of machinery in order to produce mass timber products both efficiently and precisely. Additionally, as more manufacturers develop advanced lamination processes—such as cross-laminated timber—they will also need to invest in more advanced industrial infrastructure, more highly-skilled employees, and closer ties to resource centers. The mass timber industry represents a highly promising future for many rural areas in New England that are rich in forest resources but currently lack viable industrial economies.

Top: Grading and sorting lumber at Nordic Structures involves scanning viable timber with highly precise computational equipment, allowing Nordic to maximize the dimensional lumber provided by Chantiers Chibougamau.
Middle: A massive glue-laminated beam is constructed in Nordic’s fabrication facility. Each beam contains over 4,000 cubic meters of lumber and is separated into three sections for production and transportation to the construction site.
Bottom: Each beam is outfitted with steel connections that require 416 14 mm wood screws. A fabrication technician utilizes a computerized torque wrench that is able to calculate the maximum loads of torque placed on each wood screw.
**Common Ground High School**

In 2011, Gray Organschi Architecture was selected to design Common Ground High School, an environmental charter school in New Haven, Connecticut. Along with Atelier 10 Environmental Engineers, the design team was tasked to create a building that embodied the environmental pedagogy of the school. In response, Gray Organschi Architecture proposed a building that integrated new ecological concepts, exposed sustainable technologies, and exploited the structural capacities and ecological benefits of wood fiber. It is one of the first buildings in the United States to use cross-laminated timber (CLT) as its primary structure. One notable benefit of this aggregation of construction biomass is that the carbon sequestered in the building’s structural system offsets the annual emissions of 95 cars, making the building carbon neutral in its first decade of operation.

**Regional Impacts**

This integrated use of renewable material and low-impact construction technique enhances the health and ecological function of the immediate site. It also protects more distant productive landscapes, optimizing their biological and hydrological processes so that they may continue to provide valuable environmental services such as clean air and water (and a steady supply of renewable building material) to our cities. Having designed and constructed Common Ground High School as a successful example of a vertically integrated timber supply chain, Gray Organschi Architecture and Its Timber City partners are now developing a case study project in New Haven's Ninth Square district.

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**447 mT CO2 Embodied in Structural Timber**

95x annual emissions of a standard American car

- **CLT** 46.02 mT CO2
- **Glulam** 88.72 mT CO2
- **Joists/Rafters/Studs** 14.97 mT CO2
- **Sheathing** 30.83 mT CO2
- **Cellulose Insulation** 49.71 mT CO2
- **Dimensional Lumber** 12.95 mT CO2

*Unlike timber, concrete and steel do not have the latent capacity to sequester carbon*
CASE STUDY SITE SELECTION

Now Haven's Ninth Square district is the proposed site for studying the potential for mass timber to effectively integrate with and transform the existing urban fabric. As the last of New Haven's original nine squares to develop, the Ninth Square district presents an archetypal story of cities along the Northeast Corridor. During its boom in the late nineteenth and early twentieth centuries, the Ninth Square was home to a dense fabric of three to five story masonry buildings that created a lively commercial district.

During the mid-twentieth century, the arrival of two major interstates, I-91 and I-95, disrupted the Ninth Square's connection to the waterfront and to residential neighborhoods to the south. In 1968, the city constructed the New Haven Coliseum, a massive entertainment and sports venue that catered to audiences arriving via automobile. This focus on vehicular transportation, and a failure to include more pedestrian-oriented businesses along the street, ultimately led to the demolition of many buildings in the Ninth Square in order to sustain the demand for more parking.

SITE OPPORTUNITIES

Today, many of these lots remain either vacant or occupied by surface parking. Yet despite these voids in the urban fabric, the district has transformed into one of the most vibrant parts of the city, boasting a large arts community, small businesses, restaurants, and a high density of multifamily housing. With the archetypal New England urban fabric, poised at the cusp of an urban resurgence, and rich with a variety of vacant lots awaiting infill development, New Haven's Ninth Square presents an ideal site to construct a Timber City.

1. 1 Church Street
   1.00 Acres
   BD-1 - FAR 8.0
   PARTY WALL
   INFILL

2. 110 Crown Street
   0.15 Acres
   BD-1 - FAR 8.0
   INFILL
   CORNER

3. 55 Crown Street
   0.97 Acres
   BD-1 - FAR 8.0
   CHANNEL
   CORNER

4. 642-3 Chapel Street
   0.4 Acres
   BD-1 - FAR 8.0
   PARTY WALL
   CORNER

5. 50 Crown Street
   0.26 Acres
   BD-1 - FAR 8.0
   CORNER
   INFILL

6. 812 Chapel Street
   0.16 Acres
   BD-1 - FAR 8.0
   CORNER

7. 192-196 State Street
   0.62 Acres
   BD-1 - FAR 8.0
   CORNER

8. 860 Chapel Street
   0.7 Acres
   BD-1 - FAR 8.0
   CORNER

9. 232 State Street
   0.4 Acres
   BD-1 - FAR 8.0
   CORNER

10. 19-25 George Street
    0.31 Acres
    BD-1 - FAR 8.0
    INFILL

11. 31 George Street
    0.14 Acres
    BD-1 - FAR 8.0
    CORNER

United States housing starts between 2003-2014, differentiated by housing type and scaled to demonstrate relative growth patterns between single-family and multifamily housing.

timber city © 2016 Gray Organschi Architecture
Timber City is an interdisciplinary research initiative comprised of experts from forestry and material science, the wood products and timber fabrication industries, engineering and architectural design, building finance and development, and urban planning and governance.

It is an ongoing project of Gray Organschi Architecture with support from the Yale School of Architecture, the Roger Williams University School of Art, Architecture and Historic Preservation, the Hines Research Fund for Advanced Sustainability at Yale and the American Academy of Arts and Letters.

Our partners contribute a broad and deep base of knowledge and creativity capable of producing a comprehensive approach to forest resiliency, rural and urban economic economic development, and sustainable construction in the 21st century.
How will we suitably house growing populations, effectively address climate change, and ensure a vibrant and sustainable economy? Timber City engages an architectural exploration of these most urgent challenges facing the urban built environment. Timber City contemplates new materials and methods that will necessarily drive commercial innovation in raw material extraction, supply chain management, labor force and financing strategies. The New Haven pilot will provide an important learning laboratory for regulators and industry. I am pleased to endorse the Timber City initiative. We look forward to the opportunity to participate and learn from this important exploration into the future of building technology, urban infrastructure and design.

Joe Weisbord
Director, Credit and Housing Access, Fannie Mae

"Timber City will build on the work that Gray Organschi Architecture has already done to advance wood construction as a sustainable approach to the built environment. This work will advance a crucial approach for reducing the extent and impact of global climate change, and will help set the stage for sustainable forestry in New England and beyond—thereby supporting rural economic opportunity and long-term forest health. The work will resonate from the urban core to the wild forests of northern Maine, sounding a note of hope for the future."

Frank Lowenstein
Deputy Director, New England Forestry Foundation
Senior Fellow, US Department of State, Energy and Climate Partnership of the Americas
Lecturer in Environmental Studies, Brandeis University

The Timber City Initiative brings to demonstration and fruition three elements of focus of the Global Institute of Sustainable Forestry at Yale University:
1. the use of wood, which is much less polluting than the traditional urban building materials such as concrete, steel, and brick;
2. the provision of many rural, skilled jobs of good wages in harvesting and processing the wood in environmentally sound ways;
3. the appropriate management and monitoring of forests to provide the environmental services of biodiversity, fire protection, water quality, and others.

The Global Institute has studied the relation of forests and wood use to carbon sequestration. We have found that wood construction can dramatically reduce the CO2 emissions and fossil fuel consumption when used as a substitute for concrete, steel, and brick.

The lack of skilled jobs in rural areas forces many people to move to cities and creates a downward spiral in the rural economy. We are working on ways that appropriate technologies in wood harvesting and manufacturing could provide good wages to many people. The emphasis is on greater skill in more workers and less investment in heavy, expensive, and potentially damaging logging equipment.

We have found that relatively little of the world's annual growth of wood is being harvested; much of it is increasing forest biomass, dying, or burning up. The result is that forests are becoming uniformly overcrowded. Consequently, there is a growing lack of diversity of habitats and the crowded forests are burning and releasing CO2 to the atmosphere. Appropriate silviculture done by skilled woods workers (2, above) in conjunction with removing and utilizing the excess wood can enhance the forests ecosystem services. The Global Institute is working on technical tools including G.I.S. that enable people to plan, manage, and monitor their forests sustainably while providing more ecosystem services.

Chad Oliver
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Mary Tyrrell
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