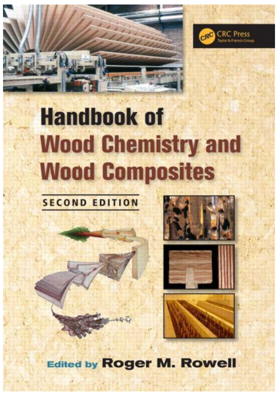

Handbook of Wood Chemistry and Wood Composites

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Sustainability of Wood and Other Biomass

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18 Sustainability of Wood and Other Biomass

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CONTENTS

18.1 INTRODUCTION

The question can be asked, "why study wood chemistry?" Why would so many authors take their time to write a book on wood chemistry and wood composites? The simple answer is that wood and other biomass can be part of a sustainable materials future. However, wood and other biomass will not reach it highest potential until we understand its chemistry and materials properties and how these express themselves in performance. As our supply of nonrenewable resources runs out and becomes more expensive, we must turn out attention to renewable resources. Up until about 1920, almost all of our chemicals and materials were derived from wood. Then our dependence on petroleum, steel, aluminum, glass, plastics, and other synthetics started to grow. Today, we rely heavily on petroleum for our energy, metals, ceramics, and plastics for our materials but these resources are not sustainable.

The simplest definition of sustainability of wood and other biomass is to not use more today that you can replace tomorrow. Sustainable development can be achieved using a long-range proactive dynamic strategic plan that focuses not only on short-term profits and competitiveness without damage to the environment but maintains an equal emphasis on future maintenance and growth of the society. Sustainable development must fit certain criteria within a framework of economic, environmental, and social systems before it can last indefinitely. If we consume more than nature can replenish, we are in a state of environmental degradation that is not sustainable. If we only harvest and use what nature can replenish, we are in environmental equilibrium. If we consume less than what nature can replenish, then we have achieved an environmental renewable state and sustainable indefinitely.

We must create a closed loop in our use of forest resources. About 50% of the dry weight of wood is carbon. Growing trees take in carbon dioxide through the process of photosynthesis and convert it to tree biomass. The carbon dioxide is released again when the wood decays or burns. Thus, sustainable forest management systems study input carbon from photosynthesis, use carbon in products and carbon back into the atmosphere during combustion or decay.

We will have to live off of nature's income not its capital or we may find fewer choices and flexibility in our future lives. There will be resistance to change in the way we live but we must strive to become a sustainable society and integrate environmental, social, human, and economic needs into our policies and activities. We must set sustainable goals and achieve them both locally and globally.

In general, our present business economic model is focused on short-term profits. The "bottom line" for most companies is the black ink quarterly gains to stockholders. While this model will and must remain critical, a new economic model must be developed that gives credit for long-term survivability and sustainability of a business. It is interesting that historically the concept of sustainability comes from a German forest in the seventeenth century. They limited the number of trees that could be harvested for firewood to the number of new trees planted. The German word for sustainability is Nachhaltigkeit and was first mentioned in an eighteenth century treatise on forestry by Hans Carl von Carlowitz (Sustainable Times 2008). The English translation of this text is "sustainable yield."

Environmental sustainability is a direct result of this early German concept that is to use our natural resources only as fast as they can be regenerated. Sustainable forestry must integrate the elements of forest health, economic profitability, and social equity. In simpler terms, the concept can be described as the attainment of balance—balance between society's increasing demands for forest products and benefits, and the preservation of forest health and diversity. This balance is critical to the survival of forests, and to the prosperity of forest-dependent communities (Sathre 2007).

The modern concept of sustainability has it roots in a 1980 meeting of the International Union for the Conservation of Nature. They published the *World Conservation Strategy* and first used the term "sustainable development" (WCS 1980). Later in 1983, there was a meeting of the United Nations World Commission on Environment and Development (WCED 1983). The General Assembly passed Resolution 38/161 "*Process of preparation of the Environmental Perspective to the Year 2000 and Beyond*." It established a Commission to be chaired by the former Norwegian Prime Minister Gro Harlem Brundtland and its mission was to address growing concern "about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development." In establishing the commission, the UN General Assembly recognized that environmental problems were global and that it was in the best interest of all nations to establish policies for sustainable development. The new commission was to "(1) propose long-term environmental strategies for achieving sustainable development by the year 2000 and beyond; (2) recommend ways in which concern for the environment may be translated into greater co-operation among developing countries and between countries at different stages of economic and social development; (3) lead to the achievement of common and mutually supportive objectives which take account of the interrelationships between people, resources, environment and development; (4) consider ways and means by which the international community can deal more effectively with environmental concerns, in the light of the other recommendations in its report; and (5) help to define shared perceptions of long-term environmental issues and of the appropriate efforts needed to deal successfully with the problems of protecting and enhancing the environment, a long-term agenda for action during the coming decades, and aspirational goals for the world community" (WCED 1983, pp. 48–50).

In 1987, the report from the Brandtland Commission defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (BC 1987, p. 3).

In 1989, following the publication of the Brundtland Report, Swedish scientist, Karl-Henrik Robèrt published *The Natural Step* outlining the basic principals to help bring societies towards sustainability. The core message of *The Natural Step* is to help people from all over the world discuss environmental issues without getting bogged down in details or disputes (*The Natural Step* 1989). *The Natural Step* is derived from the first and second laws of thermodynamics: that energy is conserved and nothing disappears (all matter that will ever exist on Earth is now here) and that matter and energy tend to disperse over time (disorder increases in all closed systems). Applying these two laws into *The Natural Step* there are four system conditions: (1) "Nature cannot withstand a systematic buildup of dispersed matter mined from the Earth's crust; (2) Nature cannot withstand a systematic buildup of persistent compounds made by humans; (3) Nature cannot take a systematic deterioration of its capacity for renewal; and (4) if we want life to continue, we must (a) be efficient in our use of resources and (b) promote justice—because ignoring poverty will lead the poor, for short-term survival, to destroy resources that we all need for long-term survival."

18.2 ECONOMIC, ENVIRONMENTAL, AND SOCIAL FACTORS

The 2005 World Summit Outcome Document refers to the "independent and mutually reinforcing pillars" of sustainable development and must fit certain criteria within a framework of economic, environmental and social systems before it can last indefinitely (Figure 18.1, World Summit 2005). Each component of this framework is important and no component is more important than the other. Each element not only influences each other but also depends on each other. Using this model, Figure 18.1 shows how the three concepts fit together. The model does not rely on only one system but all three and the interface of the three systems shows areas that are bearable, viable, and equitable with a core intercept of sustainability. What is good for society may not be good for the environment and may not make long-term economic sense. It is within the core sector that sustainability can be achieved.

The model shows that there are areas that are bearable between the society and the environment, areas that are equitable between society and economic considerations and viable between the environment and the economics but only when the three are taken as a whole can the given situation become sustainable. The "bottom line" for this model requires a long-range proactive dynamic strategic plan that focuses not only on short-term profits and competitiveness without damage to the environment but maintains an equal emphasis on future maintenance and growth of the society. This new model also assumes that the long-range plan will maintain a quality of life indefinitely.

Western countries use approximately 30 times more resources than developing countries and countries such as China and India are striving to reach a western style of living. Taking these three factors into the future it is apparent that we cannot maintain the status quo and the present "business as usual" is not sustainable.

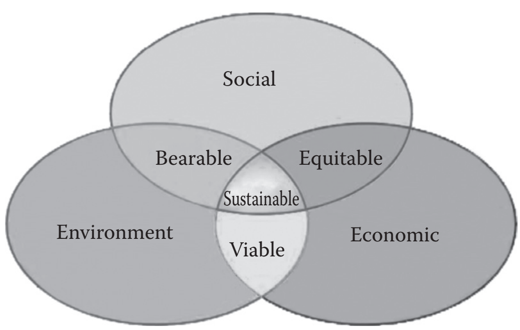

FIGURE 18.1 Model of the interaction between social, environmental and economic factors in sustainable development. (Adapted from World Summit 2005. United Nations 2005 World Summit. UN Headquarters, New York, NY (www.un.org/summit2005).)

18.3 GREEN AND SUSTAINABLE

The concept of green or environmentally friendly technologies can be in conflict with sustainable development in that green technologies gives priority to environmental considerations over those of economics and cultural considerations. An example of this might be a community that decides it will start a recycling program to reduce the amount of trash going into the local landfill. The cost of the program is expensive and there is no market for some of the recyclables so the program is environmentally sound but nonsustainable due to economics. Another example might be the desire of a society to convert corn into ethanol as a fuel supplement. This causes a higher price for corn which results in an increase in both animal feed and human food. In the long term, this may prove not to be sustainable.

18.4 ELEMENTS OF SUSTAINABILITY

There are several critical elements in a sustainable future. These include raw material supply, water, energy, emissions and waste products, product viability, human resources, and technology development (Rowell et al. 2010).

18.4.1 Raw Material Supply

It has been said that the twenty-first century will be called the era of cellulosics. However, we have to remember that wood is not renewable; the tree it came from is renewable. This puts our focus on healthy ecosystems to maintain a renewable supply of wood. Wood is not the only source of lignocellulosics. The forest industries must look to other sources of biomass for composite products. Composites such as fiberboard and particleboard can also be made from agricultural resources. Table 18.1 shows an inventory of the world supply of agricultural resources that are available for utilization (Rowell 2002).

If we consume more than nature can replenish, we are in a state of environmental degradation that is not sustainable. We must work toward a stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, and vitality.

TABLE 18.1
Inventory of World Bio-Resources

Source	Metric Tons
Wood	1,750,000,000
Straw	1,145,000,000
Stalks	970,000,000
Bagasse	75,000,000
Reeds	30,000,000
Bamboo	30,000,000
Cotton staple	15,000,000
Core fiber	8,000,000
Papyrus	5,000,000
Bast fiber	2,900,000
Cotton linters	1,000,000
Grasses	700,000
Leaf	480,000
Total	4,033,080,000

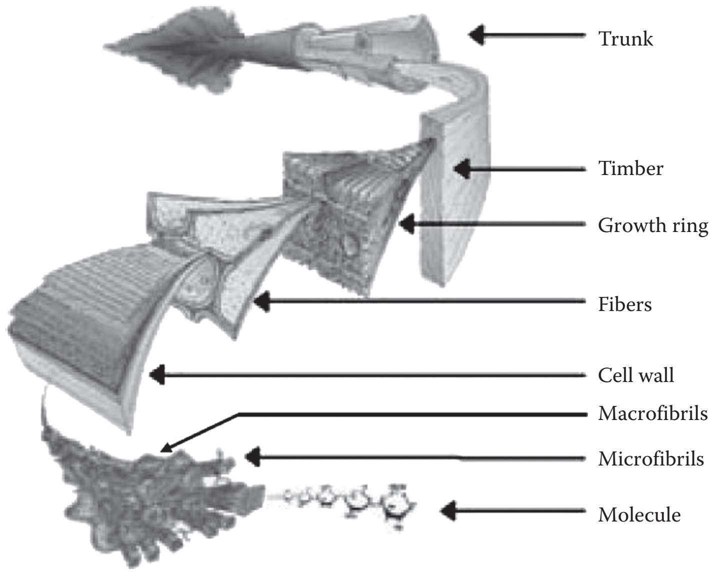

FIGURE 18.2 Possible product levels from a tree.

Figure 18.2 shows the possible product sizes that can come from a tree (see Chapters 10, 12, 13). With a Young's modulus of about 10 GPa for solid wood, 40 GPs for wood fibers, 70 GPa for microfibrils and 250 GPa for cellulose crystallites there are many possible biomaterials that can be produced from wood with a wide variety of furnish sizes and strengths.

18.4.2 Water

Seventy percent of the Earth's surface is covered with water, however, most of this water, 97.5%, is in the oceans and seas and is too salty to drink or grow crops. Of the remaining 2.5%, 1.73% is in the form of glaciers and icecaps leaving only about 0.77% available for our fresh water supply. Of the total water on Earth, only 0.0008% is available and renewable in rivers and lakes for human and agricultural use. It is the water that falls as rain or snow or that has been accumulated and stored as groundwater that we depend on for our "clean" water resource (Rowell 2006).

For 1.5–2.5 billion people in the world, clean water is a critical issue. It is estimated that by the year 2025, there will be an additional 2.5 billion people on the Earth that will live in regions already lacking sufficient clean water. In the United States, it is estimated that 90% of all Americans live within 10 miles of a body of contaminated water. Contaminates in water include sediments, nutrients, pathogens, dissolved oxygen, heavy metal ions, suspended solids, pesticides, turbidity, fish contamination, and ammonia.

In 1990, the average water consumed per person was 1620 gallons per day and in 2000 this had decreased to 1430 gallons per day (USGS 2000). In 2000, 408 billion gallons per day were consumed. Sixty-nine percent of this water came from surface water the remainder from ground water. Thermoelectric-power plants consumed 195,000 million gallons per day (Mgal/d), 137,000 Mgal/d for irrigation, and 43,300 Mgal/d for household use. Of the household water consumed, 4% was for drinking, 20% for watering gardens, 32% for toilet flushing, 28% for bathing and cleaning, and 16% for laundry and dishes.

Future water use considerations must focus on reuse and closed-loop systems where waste water is kept to a minimum.

18.4.3 Energy

Since the start of the industrial revolution, the worldwide use of energy has had a steady growth. In 1900, the global energy consumption was 0.7×10^{12} Watts (watt = 1 joule per second) (KWE 2006). In 2005, the total world consumption of energy had increased to 5×10^{20} Joules with 85% of this energy coming from the combustion of fossil fuels (Energy Information 2006). From 1980 to 2004, the increase in global energy consumption increased 2% per year. The United States consumes approximately 25% of the total world energy.

The consumption of fossil resources puts what might be called historic or ancient carbon into the environment. Once these fossil resources are gone, they cannot be replaced. Burning of biomass for energy puts what might be called recyclable or modern carbon into the environment meaning that the small amount of carbon coming from the burning of biomass can be recycled into the photosynthetic pathways. Not so with the large amount of historic carbon.

Globally, on a percentage basis, 37% of our energy comes from oil, 25% from coal, 23% from gas, 6% from nuclear, 4% from burning biomass, 3% from hydro, 0.5% from solar, 0.3% from wind, and 0.2% for geothermal. It is estimated that there are global reserves of 290 zJ (1 zetta joule = 10^{20} joules) of coal, 19 zJ of oil, and 16 zJ of gas left. Coal is the most abundant fossil having a reserve of over 909 billion tons.

It is projected that our future consumption of energy is expected to jump 50% by 2030 and oil could cost between \$113 and \$186 a barrel (Hargreaves 2008). In 2012, this projected cost for oil seems very low and the actual cost may be much higher than this. Our future energy needs must be greatly reduced and may depend on sun-driven processes. The sun produces approximately YJ per year (1 YJ = 10^{24} J) or 8000 times the 2004 total energy usage.

18.4.4 Emissions and Waste Products

Emissions and waste products (pollutants) come from all human activity. Carbon dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds, particulate matter, toxic metals, ammonia, chlorofluorocarbons, and radioactive pollution are the result of this activity. The gasses are causing an increase in global warming and sea levels rising. The solids are polluting our water, soil, and filling up our landfills. There is an advertisement from the Royal Dutch Shell Company that states, "Don't throw anything away. There is no away."

Table 18.2 shows the carbon footprint of bio-resources in the United States from 1910 to a projection on 2040 (USDA 2000). Part of the carbon is sequestered in products, part goes to the landfill, part to energy, and the rest to emission due to decay.

By 2000, the percentage of carbon going into products had come back to the level in the early part of the twentieth century and represents sequestered carbon. This was also true for burning

TABLE 18.2
Carbon Footprint of Bio-Resources in the United States in Trillion Tons

Year	Added to Products	Added to Landfills	Burned for Energy	Decay Nonenergy
1910	24.3	1.1	88.4	10.6
1920	22.9	3.1	51.9	14.7
1940	14.0	5.3	35.0	20.4
1960	9.0	7.1	34.6	30.6
1980	11.8	27.9	48.1	19.2
2000	25.0	32.5	88.1	14.3
2020	25.6	42.6	103.0	16.4
2040	22.9	50.8	119.0	17.5

biomass for energy. The largest increase in the carbon footprint is what the United States put in its landfills. The projections for the year 2020 and 2040 indicate a large increase in burning for energy and landfilling with little increases in carbon added to products or carbon lost due to decay. We must always work to minimize resource use and to minimize wastes.

18.4.5 Product Viability

Along with strategies to remain sustainable in terms of raw material supply, water use, energy, and emissions/wastes is product viability. It is well known that at the turn of the nineteenth century the world had developed the best buggy whip ever made but there was no need for this tool since the era of the horse had passed. In order for a product to remain viable it is vital to make sure it is still needed and relevant in the modern society.

In general, the forest industry makes incremental improvements in the present technology, however, it is mainly universities and institutes that develop new technologies. It will be critical to continue research in the development of new technologies to insure a continuing supply of sustainable products.

18.4.6 Human Resources

There is no substitute for a well educated and competent human capital. New technologies must be developed and that comes from imagination, risk taking, experience, and vision. We cannot afford to lose skills and specialization. It is hoped that this book will help educate future generations in wood chemistry and wood composites.

Unfortunately, with the downturn in the forestry industries, fewer universities are teaching courses in wood science. If students cannot get a job in the industry, there are fewer students in that subject. This forces universities to reduce staff in those departments with few students. If forest resources make a comeback in a sustainable society, it will take years to rebuild the expertise that once existed in our universities and institutes.

Future generations must think new thoughts and new ways of doing things. Albert Einstein said that “Today’s problems cannot be solved if we still think the way we thought when we created them.” There is an old Chinese proverb that states “Unless we change direction, we are likely to end up where we are going.”

18.4.7 Technology Development

There must be constant and continuous improvements in technology to ensure that development remains sustainable. If any element in a sustainable project becomes unsustainable, then new technologies must be developed to get the project back in a sustainable mode. Life cycle management must be a dynamic part of all existing and new technologies. Within the life cycle assessment we must continue to analyze inventory, impact, and improvements of past, present, and future technologies. Innovation, research and development, and market integration must be part of all sustainable traditional and new businesses. Emphasis must be placed on carbon sequestration to reduce the carbon going into our atmosphere.

18.5 THE R’S OF SUSTAINABILITY

There are many “R’s” in sustainable development: reduce, reuse, recycle, regulate, renovate, reinvent, reconsider, refresh, and respect. We must reduce our use of raw materials, energy, water, and emissions and wastes. We must find ways to reuse and recycle materials. There is a natural resistance to change so we must act by changing laws and regulations to force change. Instead of building new we must consider renovation of existing structures. We must reinvent, refresh, and update technologies to keep them relevant. Anthony Cortese, president of Second Nature added two more R's to this list, rethink (our use of materials) and refuse (to continue to consume). Finally, we must respect our environment so life on planet Earth can be sustained.

18.6 MAKING CHANGE HAPPEN

Sustainability is a concept that most support but few understand what it means in practice. Making the transition from our present economic model to one of sustainability is a process that will take time and great effort. It will be done in small realistic steps and it will be the responsibility of all involved in the system: workers, policymakers, researchers, companies, and consumers. It will be a dynamic process and we must be proactive not reactive to change.

It is easy to think that the other person will make the changes needed for us to become a sustainable global society. Do not wait for a grand scheme to come along to move society forward. Society is no more than a collection of "us." It is up to each of us to be involved. Margaret Mead said that "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has." And, Mohandas Gandhi said "you must be the change you wish to see in the world."

We may find less choices and flexibility in our future lives. There will be resistance to change in the way we live but we must strive to become a sustainable society and integrate environmental, social, human, and economic needs into our policies and activities. We must set sustainable goals and achieve them both locally and globally.

18.7 CONCLUSIONS

The wood industry has the raw material supply, its own energy supply and a wide range of possible products from timbers, lumber, veneers, chips, flakes, particles, fibers, polymers, and chemicals that can be produced from a biorefinery concept, knowledge to produce adhesives and coatings from biomass and technology to increase stability and durability of biomaterials. New breakdown, separation, and synthesis technologies will be developed that will use less energy and water in conversion into products. We must make sure that our forests and agricultural lands are maintained and improved so that we can assure a sustainable supply of raw materials far into the future. So, why study wood chemistry? Wood and other biomass will be a major part of a global sustainable future.

Treat the Earth well, it is not inherited from our parents, it is borrowed from our children.

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