SUSTAINABLE CONSTRUCTION IN THE USA: PERSPECTIVES TO THE YEAR 2010

G.L.M. AUGENBROE
College of Architecture, Georgia Institute of Technology, Atlanta, USA
A.R. PEARCE
Georgia Tech Research Institute, Atlanta, USA

Abstract

The migration towards a more sustainable construction industry is influenced by many drivers for change, the effects of which are hard to predict. The paper introduces one possible framework, which defines indicators of change and positions them properly in the wide context of sustainable construction. Its purpose is to support the causality that needs to be established between current construction practices, the momentum created by new initiatives and policies, and indicators of change. These indicators can also be used, through proper measurement and extrapolation, to forecast opportunities for improvement and priorities for change through new policies and incentives.

An important monitoring instrument is the gathering of empirical data about perception and acceptance rates among the broad range of stakeholders in the building industry. The paper concludes with the first results of an ongoing survey of perceptions and beliefs about sustainable construction among U.S. construction experts and leaders.

Introduction

This paper surveys different aspects of sustainability of the US construction industry. It reiterates the main ideas expressed by the authors in a recent global CIB study on sustainable development [10], and gives the first account of an expert survey as follow-up on this study.

Both globally and in the United States of America (USA), the construction industry is one of the main contributors to the depletion of natural resources and a major cause of unwanted side affects such as air and water pollution, solid waste, deforestation, toxic wastes, health hazards, global warming, and other negative consequences. And although the traditional attitude of having unlimited resources and space is still dominant in the USA, the awareness of environmental impacts is growing and many movements seeking to address sustainability concerns are gaining momentum.

Buildings represent more than 50 percent of the nation's wealth in the USA. In 1993, new construction and renovation activity amounted to approximately $800 billion, representing 13% of the Gross Domestic Product, and employed ten million people [1]. Buildings account for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest and two-fifths of its material and energy flows [2]. Nearly one-quarter of all ozone-depleting chlorofluorocarbons (CFCs) are emitted by building air conditioners and the processes used to manufacture building materials [3]. 54% of U.S. energy consumption is directly or indirectly related to buildings and their construction [4]. Urban settlements affect local ecosystems, air, water, and soil quality, and transportation patterns of communities, thus having additional impact on the sustainability of our society. It is paramount that the building industry adopts 'environmental performance' as one of its leading principles alongside economic efficiency and productivity principles.

Specific national concerns in the USA are many. The nation has a wide diversity of climatic zones, and traditional building technologies vary from region to region. Severe winters, hot summers, and variations in climate from northern sub-arctic to desert and subtropical present different sets of bioregional sustainability issues. Because of this diversity and the legal domination by individual states in controlling construction practices, building codes vary from state to state. There are more than 76 million residential buildings and almost 5 million commercial buildings in the USA, with an additional 15 million buildings projected by the year 2010 [5]. Existing buildings use more than one-third of all primary energy consumed in the country, and account for two-thirds of the total electricity use. Lighting accounts for 20-25% of the electricity used in the U.S. annually [3]. Offices in the U.S. spend 30 to 40 cents of every dollar spent on energy for lighting power, making it one of the most expensive and wasteful building features [3]. Over 30% of the total energy and 60% of the electricity use in the United States is in buildings [6]. This energy use produces nearly one-quarter of the country's total carbon emissions, a significant contribution to climate change. In addition to energy considerations, many regions suffer from air and water pollution. Despite the seriousness of present impacts, considerable progress has been made and both air and water are cleaner than they were a few decades earlier.

Another national concern is inner city decay. Urban infrastructure has steadily deteriorated in recent decades, causing a focus on the revitalization of the nation’s inner cities. These blighted inner cities represent a cross section of socially and environmentally unsustainable communities, with decreasing property values and declining neighborhoods. Present inner city problems may be a harbinger of the problems of the “megacities” of the future. Other important local and national issues concern an estimated 400,000 brownfield sites nationwide and the effects of urban sprawl.

Important constraints for change are posed by the recent wave of deregulation that is sweeping the country and the fact that sustainability in the USA is primarily a community-driven, grass roots movement.

Sustainability and the US construction industry

The complex problems shared by cities throughout the USA are evidence of the impacts of urban sprawl: increasing traffic congestion and commute times, air pollution, inefficient energy consumption and greater reliance on foreign oil, loss of open space and habitat, inequitable distribution of economic resources, and the loss of a sense of community. These combined pressures, along with the challenges faced specifically by stakeholders of the built environment, have led to a growing awareness of the need for change.

In response to these drivers of change, the concept of sustainability is beginning to permeate the US construction industry as a possible strategy to better meet the needs of clients and owners while ensuring success in an increasingly competitive and constrained operational environment. While a variety of initiatives have been put into place to begin the change toward increased sustainability (see Table 1), some people have begun to realize that these initiatives are not sufficient to bring about the change that is needed. Aiming for a sustainable built environment requires more than disconnected, although widespread, incentives: it requires a fundamental paradigm shift in the way we approach time, cost and quality constraints [7].

Sustainability as a performance issue forces us to take a much broader look in both time (full life cycle assessments), space (the object in its wider system settings) and costs (greener cost metrics than pure monetary), than we used to do in traditional engineering. This wider perspective can be made operational through the introduction of a suite of sustainability indicators, as presented in Section 3.

Indicators of Sustainable Construction

Given the broad range of issues and challenges facing the USA in its quest for creating a sustainable built environment, stakeholders desperately need a consistent framework of indicators to measure progress and set research agendas. This section introduces one possible framework to classify sustainability indicators. The framework is used to define indicators of change and position them properly in the wide context of sustainable construction. Its purpose is to support the causality that needs to be established between the current situation, expressed by a set of indicators, the momentum created by new initiatives and policies, and indicators of change.

These indicators of change can also be used, through proper measurement and extrapolation, to forecast opportunities for improvement and priorities for change through new policies and incentives. Figure 1 defines sustainable construction in a methodological framework, consisting of three main axes: System (boundary), Process (actor), and Aspect (sustainability). It expresses that in different *life cycle phases* of a building, different *actors* are dealing with the designed or built artifact, each of them within distinct *system boundaries*, while responsible for different *sustainability aspects*.

Table 1. Selected national US sustainability initiatives

INITIATIVE	ORGANIZATION	PURPOSE
Leadership in Energy and Environmental Design (LEED)	US Green Building Council	Whole building rating system and standard for green building
Buildings for the 21st Century	US Department of Energy	Increase residential and commercial energy efficiency
Solar design guidelines and software	Passive Solar Industries Council	Facilitate the growth of solar design
Million Solar Roofs Initiative	US Department of Energy	Place one million solar energy systems on US roofs by 2010
Energy Star	US Environmental Protection Agency	Voluntary energy efficiency certification program
Green Lights Program	US Environmental Protection Agency	Voluntary lighting retrofit and certification program
Consumer Guide to Home Energy Savings	American Council for an Energy-Efficient Economy	List and comparison of the most energy-efficient appliances and equipment available
Guide to Energy-Efficient Office Equipment	American Council for an Energy-Efficient Economy	Guide to selecting and operating office equipment for maximum energy efficiency
Home Energy Rating System (HERS)	Energy Rated Homes of America	Energy efficiency rating system used to obtain Energy-Efficient Mortgages

The *system* axis spans building-internal composition levels (from material to assembled components whole building systems) to building-external macro and meso levels (building, city, ecosystem, world). Along the *process* axis, clusters of actors are connected in collaborative tasks. Depending on the scale of the observation (system boundary), different actors (individual owner, design team, regulatory bodies, government) fade in and out of focus.

Aspects are depicted as radar charts that evolve through the life cycle stages of the facility. Certain aspects are decided upon in a particular life cycle stage. They fade in and out of the design/construction/maintenance process over time. The inherent complexity of a construction project is apparent and one should realize that sustainability is just one of many performance requirements that the design, engineering and construction team is trying to meet. As such, sustainability can not be separated from improvements of the construction industry as a whole, i.e., through a more integrated and better-managed process.

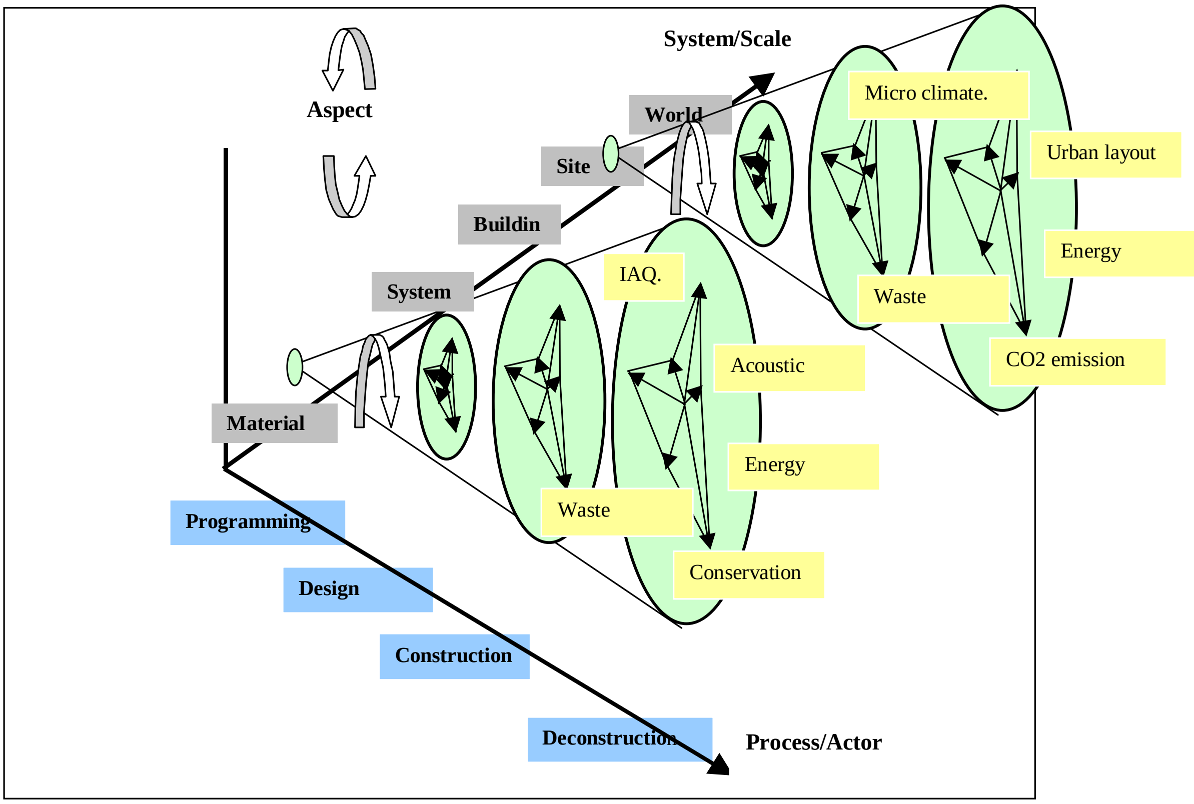

Fig. 1. A framework for sustainable construction indicators

The figure also shows the typical system specific approach to the control of desired aspects, e.g. on component level (somewhere in between material and building system level) certain aspects will be dominant whereas on other system scale (e.g. regional level) the urban development indicators will be the dominant design objectives.

On a superficial level the figure obscures the real problem, i.e. on the transition or boundaries between two system levels, between actors and across life cycle stages. Another issue that is not immediately apparent is the present lack of support for an integral comparison of different design alternatives. For the time being the 'value system' to objectively compare different envelopes on the radar chart is lacking.

Sustainable construction can now be defined in operational terms based on the set of performance aspects with suitable indicators. Along the Process axis, the need for operational instruments to optimize performance can be identified. The framework allows us to measure how different process phases deal with resources at various scales of the built environment. The ultimate goal of the operational framework is to develop the instruments to ascertain in what way the built environment can be self sustainable within system boundaries at meso or even macro levels (i.e., no inputs or outputs crossing the system boundary means fully self-sustaining). The performance indicators enable us to measure how well the 'product' performs. It is paramount that these performance metrics reflect the multiplicity of performance indicators, enabling integral performance assessments.

Along the process axis we need to measure the effectiveness of the process, i.e., how well stakeholders involved in a process phase, work together in meeting the sustainability objectives at different system boundaries. Transparency of objectives and tasks across system boundaries at different system levels is a key performance requirement, since many mistakes of the past can be traced back to a lack of task and objectives coordination.

Each system boundary poses its own set of sustainability issues apart from the issues resulting from the aggregation of its subsystems. An acute challenge is finding the system boundaries, process phases and actors that in current practice have the greatest impact on the resulting performance of the built environment.

Drivers for change in the US construction industry

Many drivers for change have emerged as a result of the US construction industry's response to sustainability. The following sections describe fifteen such drivers that have the potential to significantly influence the sustainability of the built environment in the US in the next 15 to 20 years. This list is by no means intended to be exhaustive, but rather as a point of departure in the assessment of effectiveness of the individual drivers and their prioritization by experts in the field.

Energy conservation measures

Measures to improve the energy efficiency of buildings hold tremendous potential. The Congressional Office of Technology Assessment estimates that commercially available, cost-effective energy technologies could reduce overall energy consumption in the USA by as much as one-third--worth some $343 billion. Strategies such as proper siting and airtight construction, as well as installing energy-efficient equipment and appliances and renewable energy systems will reduce the amount of energy a building needs to operate and to keep its occupants comfortable.

Buildings for the 21st Century is a national approach to create a new generation of buildings that are energy efficient, high quality, affordable and environmentally sustainable. With this approach, the US uses energy efficient and solar technologies and designs now available to save 20% of the energy currently used in buildings, and to reduce the energy use of new buildings by 50% relative to present building practices.

Current policies are aimed at a market-based approach, recognition of clean energy alternatives, collection of empirical evidence that a policy is effective, and long-term orientation. Some ‘winners’ indicate that there is reason for optimism: R&D of renewable energy has brought down the cost of renewables to the point that wind energy competes favorably with conventional electric power in some areas of the country. The government’s natural gas policy, which promotes competition, has produced a market that is supported by ample supplies at reasonable prices. Technology innovation, aided by government energy efficiency policies, has resulted in improvements in the efficient use of energy, even in the face of declining energy prices.

Land use regulations and urban planning policies

From 1970 to 1990, the density of urban population in the USA decreased by 23 percent. From 1970 to 1990, more than 30,000 square miles (19 million acres) of once-rural lands in the USA became urban, as classified by the USA Census Bureau. From 1969 to 1989, the population of the USA increased by 22.5 percent -- and the number of miles driven by that population ("vehicles miles traveled" or "VMT") increased by 98.4 percent.

There is no question that placing green building projects within easy access of public transportation, medical facilities, shopping areas, and recreational facilities decreases the need for automobiles and encourages bicycling and walking. In addition, successful green buildings blend into the community, preserving natural and historical characteristics, and will utilize existing infrastructure in order to reduce sprawl.

Waste reduction measures

Construction-related waste accounts for about one-fourth of total landfilled waste in the USA. Yet many construction materials can be recycled, including glass, aluminum, carpet, steel, brick, and gypsum. Construction and renovation waste can be reduced by salvaging, rather than landfilling, including items that have some remaining life, such as appliances, household goods, office equipment and furniture, and building materials. Construction waste can also be reduced or minimized by designing buildings to use standard-dimension lumber and through adaptive reuse (renovating existing buildings, rather than destroying them and erecting new ones).

Recycled Content Materials: There are already many building products available today that are manufactured from recycled materials. For example, organic asphalt shingles contain recycled paper, and some shingles are made from re-manufactured wood fiber. Cellulose insulation is manufactured from recycled newspaper. Alternative building materials can conserve resources, as well. Technologies that allow more efficient use of lumber include stress-skin panels; engineered framing products, such as I-beams, glue-laminated products, and finger-jointed lumber. These products allow for the use of "scrap" lumber that might otherwise be landfilled, as well as the use of small-dimension lumber.

Materials Reuse: Lumber and other products, such as windows, doors, cabinets, and appliances, can be salvaged when buildings are demolished or rehabilitated.

Resource conservation strategies

Use of waste and recycled building materials: Opportunities in this area will depend mostly on the introduction of new materials on the market and emerging brokerage services to re-use building materials.

Water conservation: Installing energy-efficient appliances and fixtures, and changing irrigation practices and behavior can reduce water consumption by 30 percent.

Indoor environmental quality

Energy-efficient buildings are more airtight and therefore hold greater potential for indoor air quality problems. Because many building products can contribute to poor air quality, one can reduce these potential problems by selecting materials lower in chemicals and toxins, and installing mechanical ventilation systems to ensure an adequate fresh air supply. Other issues affecting indoor environmental quality include acoustical quality, lighting, texture, color, and spatial distribution of functions.

Environmentally-friendly energy technologies

Urban scale: "Cool Communities: Important improvements will result by matching available technologies with the appropriate applications. A good example is reported in DOE study [8] on a "Cool Communities" strategy applied in hot climates, e.g., in southern California. Research on the use of lighter colored reroofs, resurfaced pavements, and shade trees has found that these measures can directly lower annual air conditioning bills in Los Angeles by $200M, cool the Basin by 3 degrees C, indirectly save $160M more in air conditioning, and reduce smog by 10%, worth another $360M.

Photovoltaics: In the wake of the oil crisis in the 70's, the USA began an extensive research and development program on Photovoltaics (PVs). During the 80s, a series of full-scale tests in commercial buildings were performed. In the 90s, a few far-sighted utilities have begun to install distributed PV systems integrated in their grid, slowly shifting away from fossil energy sources. In June of 1993, DOE and the National Renewable Energy Laboratory put a $25M program in place to foster integrated PV systems in commercial buildings. The potential market for PV application in the USA is big; it is only a matter of time until market forces aided by proper government incentives will approach that market with competitive building-integrated PV systems. Similar expectations exist in other markets such as heat pumps, high performance glazing, and co-generation and wind energy.

Re-engineering the design process

Looking at the building from a "whole building" or systems engineering perspective, buildings will be viewed as integrated systems rather than a series of independent components. Incorporating this perspective into the designing, planning, and building stages can have significant effects on the outcome. For instance, efficiency improvements that might be hard to justify on their own accord are seen in a different light when they result in a smaller heating and cooling system for the building. Synergies such as these are common in building designs, but are often overlooked. Increased consideration of potential synergies will foster the use of advanced building technologies that incorporate solar and other forms of renewable energy; and an integrated approach both to new-building construction and old-building renovations.

Co-engineering strategies: Green buildings are achieved through an orchestrated activity of the team of actors involved in the process of programming, designing, construction, use and recycling of the facility. Many improvements are necessary in the orchestration of the complicated process, in order to take benefit of available technologies and products. Integrated design systems are becoming more common place in the building engineering domain [9].

Proactive role of materials manufacturers

Product manufacturers are entering a new era when all or most product information is exclusively available electronically. Companies are aware that the Internet will change the way that product data is accessed, selected, ordered, and specified during the design stages. There are enormous challenges involved in "going electronic" with present paper-based catalogues, in order to consolidate a competitive edge once companies are on the net. The designing 'demand side' will start adapting its traditional role of 'buyer' of the product to a one-to-one co-engineering relationship with the manufacturer. Such relationships enable products made to meet a sustainability performance requirements profile.

Better ways to measure and account for costs

Future buildings will actively involve the adoption of life-cycle, whole cost accounting based on economic and ecological value systems, accelerating the use of sustainable technologies and establishing the concepts of system engineering in all phases of building design, construction, financing, and operation. The move to new ways of measuring costs will also serve to educate the public about the true costs of a building's ownership, occupancy and operation, along with the energy and non-energy contributions that a properly designed building can make to productivity, personal health, comfort and sustainability. New metrics will be based on a combination of life cycle cost (LCC) and environmental life cycle assessment (LCA), with the potential of beginning a new era of cooperation in community planning, construction, financing, and the establishment of affordable housing.

New kinds of partnerships and project stakeholders

New partnerships among local governments, utilities, energy service firms, and private industries, will be formed with the goal of increasing investment in research and large-scale implementation of new practices. Specifically, sustainability is about working with community partners to increase their awareness and use of the many technologies and concepts now available, while working to advance those technologies and concepts.

Adoption of performance-based standards

The development of performance-based specifications is being undertaken in many countries of the world already. These specifications will likely be preceded by the development of performance-based building codes. Different stakeholders will benefit from performance based specifications. These specifications will improve the reliability of buildings and build in guarantees to reduce their environmental impact. Owners and manufacturers will benefit from the increasing opportunities to apply new materials and new technologies

LEED Rating system [11]: The wide spread adoption and implementation of the Leadership in Energy and Environmental Design (LEED) rating system is closely linked to performance based standards. It should be noted that LEED is unique in that it was not created by an organization representing a national government. LEED rates the environmental aspects of a building and the behavior of its occupants to arrive at a final score that results in a platinum (highest level), gold, silver, or bronze plaque being awarded. A wide range of issues are evaluated to include energy and water use, indoor health, recycling for occupants, access to mass transit, materials impacts, landscaping, construction waste management, building siting, and maintenance. If successful, the LEED Building Rating System could profoundly alter the types of buildings being created in the USA.

Product innovation and/or certification

Directories and councils fostering the development and use of new products are important catalysts for change. Certification of materials as being produced in a sustainable fashion is a very important component of sustainable construction. Wood is the dominant material in residential construction in the USA and vast quantities are consumed each year in the form of dimensional lumber, plywood, oriented strand board, and other products. The Smartwood Program of the Forestry Stewardship Council (FSC) is making inroads into traditional American forestry practices by motivating wood product companies to have their forests certified as being managed to produce a sustainable harvest and respect the plant and animal biodiversity of the forest. If Smartwood is successful in applying a strategy of simultaneously influencing consumers and producers of wood products, the forestry industry in the USA could be transformed to an activity that is truly sustainable.

Different local and national rating bodies, resource directories, environmental catalogs, and newsletters and action groups have added to increased awareness throughout the industry.

Adoption of incentive programs

The US Environmental Protection Agency (EPA) offers several programs that aim to reduce energy consumption in buildings. The Energy Star Buildings Program is a voluntary energy-efficiency program for commercial buildings in the USA. The program focuses on profitable investment opportunities available in most buildings using proven technologies. Program participants can expect to reduce their building's energy consumption by about 30 percent.

Education and training

The success of sustainability in general and sustainability in the built environment in particular is very much dependent on how institutions of higher learning respond to the ideas generated as a result of widespread interest in sustainable development. An organization known as Second Nature has as its core mission changing what is taught at American universities by embedding environmental literacy in the curriculum, and has been conducting training sessions on how to accomplish this change. A number of other organizations have similar, parallel efforts underway, including Campus Ecology, a branch of the National Wildlife Federation, and the World Resources Institute.

Recognition of commercial buildings as productivity assets

The World Health Organization estimates that 30% of all new and remodeled buildings suffer from poor indoor environments caused by noxious emissions, off-gassing, and pathogens spawned from inadequate moisture protection and ventilation, resulting in $60 billion annually in lost white-collar productivity from Sick Building Syndrome (SBS) in the U.S. alone. Several recent studies have shown that making a building environmentally responsive can increase worker productivity by 6% to 15% or more. Since a typical commercial employer spends about 70 times as much money on salaries as on energy, any increase in productivity can dramatically shorten a green building's payback period. Achieving improved productivity requires better control of indoor performance, utility, and serviceability of the built asset, better maintained through adequate investments in facility management, regular building diagnostics and proper maintenance.

US Construction Practitioner Perspectives

This section gives an account of an ongoing survey among practitioners. It was first conducted as an internet-based survey among the subscribers to a 'green building' mailing list of approximately 800 members, researchers and other building professionals, followed by a paper survey at the largest green building conference in the southeastern US. Total number of respondents was 27, from both survey deployments. Respondents included three owners, three contractors, 11 designers/architects/engineers, 10 consultants/researchers, three teachers, and eight others, including regulators, material suppliers, city engineers, and students. Participants were asked to rank the 15 drivers for change based on their significance with respect to three different considerations:

1. How important is the topic to sustainable construction in the US?
2. How much progress will be made in the topic between now and the year 2010?
3. How should the topics be prioritized in order to achieve sustainable construction?

Tables 2-4 show the outcomes of participants' perceptions in response to these three survey questions. It should be kept in mind that these results only convey a first snapshot of the ongoing survey. Although it is too early to draw conclusions, the ranking of priorities in Table 4 shows a significant trend towards the traditional priorities for change, i.e. land use, energy, and conservation whereas education scores as a high priority across the board. The re-engineering of the design process is perceived as a priority for change (table 4), but there is little belief that much will change over the next 10 years (table 3).

Table 2. Importance to sustainable construction

Drivers	**Mean**	**Rank**
Energy conservation measures	8.93	2
Land use regulations and urban planning policies	8.62	3
Waste reduction measures	8.37	5
Resource conservation strategies	8.59	4
Indoor environmental quality	8.07	6
Environmentally-friendly energy technologies	8.00	7
Re-engineering the design process	7.89	8
Proactive role of materials manufacturers	7.31	12
Better ways to measure and account for costs	7.88	9
New kinds of partnerships and project stakeholders	7.30	13
Adoption of performance-based standards	7.68	10
Product innovation and/or certification	7.16	15
Adoption of incentive programs	7.24	14
Education and training	9.31	1
Recognition of commercial buildings as productivity assets	7.33	11

Table 3. Progress between now and 2010

CIB Report Indicators:	Mean	Rank
Energy conservation measures	6.93	1
Land use regulations and urban planning policies	6.93	1
Waste reduction measures	6.44	8
Resource conservation strategies	6.19	9
Indoor environmental quality	6.93	1
Environmentally-friendly energy technologies	6.69	6
Re-engineering the design process	5.19	15
Proactive role of materials manufacturers	5.54	14
Better ways to measure and account for costs	6.00	10
New kinds of partnerships and project stakeholders	6.72	5
Adoption of performance-based standards	5.81	11
Product innovation and/or certification	6.84	4
Adoption of incentive programs	5.65	12
Education and training	6.69	6
Recognition of commercial buildings as productivity assets	5.59	13

Table 4. Priorities for achieving sustainable construction

CIB Report Indicators:	Mean	Rank
Energy conservation measures	7.78	3
Land use regulations and urban planning policies	8.78	1
Waste reduction measures	7.19	7
Resource conservation strategies	7.52	4
Indoor environmental quality	6.88	10
Environmentally-friendly energy technologies	7.27	6
Re-engineering the design process	7.38	5
Proactive role of materials manufacturers	6.28	13
Better ways to measure and account for costs	7.16	8
New kinds of partnerships and project stakeholders	5.80	15
Adoption of performance-based standards	6.92	9
Product innovation and/or certification	6.72	11
Adoption of incentive programs	6.30	12
Education and training	8.54	2
Recognition of commercial buildings as productivity assets	6.00	14

Conclusions and recommendations

Strategic measures to improve the sustainability record of the construction industry have to be based on a framework of quantifiable sustainability indicators. A repeated ‘census’ of these indicators will enable researchers, government and regulatory bodies to feel the pulse of the construction industry and set targets for improvements. This study is an attempt to lay the groundwork for a framework that identifies and quantifies the main indicators. A survey among practitioners is used to test the acceptance and completeness of the indicators for change.

As more data is collected, a continuous analysis of the results will be used to update the national USA report. Future repetition of the survey will enable to track the evolution of perceived needs for change and actual, detected changes.

References

1. National Science and Technology Council. (1993). *Title.* Washington, DC.
2. Roodman, D., and Lenssen, N. (1995). "A Building Revolution: How Ecology and Health Concerns Are Transforming Construction," *Worldwatch Paper 124*, Worldwatch Institute, Washington, DC.
3. Energy Resource Center. (1995). *Sourcebook: A Guide to the Energy-Efficient and Environmentally Friendly Features of Sustainable Design*. Southern California Gas Company, Downey, CA.
4. Kirsten Chiles, in Loken, S., Miner, R., and Mumma, T. (1994). *A Reference Guide to Resource Efficient Building Elements, 4th ed*. Center for Resourceful Building Technology, Missoula, MT.
5. US Census Bureau; http://www.census.gov/
6. Barnett, D.L. and Browning, W.D. (1995). *A Primer on Sustainable Building*. Rocky Mountain Institute, Snowmass, CO., p.59
7. Vanegas, J.A., DuBose, J.R., and Pearce, A.R. (1996). "Sustainable Technologies for the Building Construction Industries." *Proceedings, Symposium on Design for the Global Environment*, Atlanta, GA, Nov. 2-4.
8. Rosenfeld, A.H., et al. (1995). "Direct and Indirect Savings: Magnitudes and Implementation policies," *Proceedings, Symposium on Design for the Global Environment*, Atlanta, GA, Nov. 2 - 4.
9. Augenbroe, G.L.M. (1998). "A Co-engineering approach to buildings," *Proceedings, VIII Rinker Conference*, Gainesville, FL.
10. Augenbroe, Godfried and Pearce, Annie R. (1998). "Sustainable Construction in the USA; A perspective to the year 2010." *Sustainable development and the future of construction*, Bourdeau, L, (editor), CIB report 225, Chapter 14 (1998).
11. The US Green Building Council, http://www.usgbc.org