Note: This document is a summary of the complete contents of SFI's Curriculum Guide and Specifications for Sustainable Facilities & Infrastructure Training.

Executive Summary

Welcome to the Sustainable Facilities and Infrastructure Curriculum Manual developed by Georgia Tech. This manual describes the curriculum of Georgia Tech's new continuing education certificate series targeted to stakeholders of the built environment who are interested in the concept of sustainability and how it can be applied to their facilities. Our audiences will include architects, engineers, contractors, builders, developers, planners, owners, and others who are interested in the concept of sustainability as it applies to the built environment. Why might they be interested in sustainability? We hope to convince them with solid evidence that sustainability can save them money, reduce their liability, attract new customers, open new markets, and increase their competitiveness over the long term.

These courses were conceived as an alternative to the state of the art in sustainability information. While many conferences, workshops, and publications are now available that deal with built environment sustainability, few if any of these resources provide a whole systems perspective. Those that do consider whole systems generally fail to provide sufficient detail to permit practitioners to apply the concepts to their specific context. Further, those people who seek a single resource spanning the range of sustainability issues from concept to technical details will find that no such resources currently exist. This series of courses is designed to fill these gaps with two significant sources of knowledge: 1) Georgia Tech's research-based knowledge of sustainability theory, integrated problem solving, and systems analysis; and 2) the lessons and knowledge-based expertise of professional practitioners. We've designed a set of seven courses that will teach course participants how to:

- Understand what sustainability means
- Understand how sustainability might benefit their enterprises
- Measure the sustainability of current and future projects
- Understand the economic costs and benefits of this new approach
- Work with diverse teams to make sustainability happen
- Use state-of-the-art tools and resources for analysis, design, and problem solving
- Prioritize potential strategies for improving project sustainability
- Apply specific strategies to their projects.

This manual provides an overview of the design of the series, the needs and implementation challenges it was designed to address, and its target audience. Following the introduction and roadmap to the manual, each course is presented first in overview form, then with an hour by hour agenda and module descriptions for each hour of instruction. The manual concludes with a list of candidate electives for obtaining a Sustainable Facilities and Infrastructure certificate, references, and appendices containing

supporting material for the design and marketing of the first public offering of the series. Appendices include an overview of the marketing strategy, a list of speakers, continuing education topic and market surveys, a module developer's kit, recommended reading resources, software matrix, a list of acquired resources, and the official course brochure.

Introduction

The Meaning of Sustainability

The concept of sustainability is gaining increased interest by decision makers as a potential solution for the myriad of global, regional, and local problems facing society in the late twentieth century. Even as developing nations struggle with issues of overpopulation, disease, and political conflict, developed countries such as the United States must balance problems such as infrastructure deterioration, pollution, and natural habitat loss with limited economic and physical resources to solve them. Sustainability offers a new way of looking at problems on both large and small scales, seeking to ensure that the needs of humanity are met in the present without endangering the potential for future human needs to be met. In the context of built facilities, sustainability can be defined as a state of the facility system marked by stability, both internal to the system as well as in terms of its context, into the foreseeable future (Pearce 1999). In terms of this definition, a sustainable facility is one that meets the needs and aspirations of its stakeholders without net negative impacts to the resource bases or ecosystems on which the system depends for its ongoing existence (Figure 1).

Existing strategies for creating sustainable built facilities range from recycling construction and demolition waste, to designing for energy efficiency or healthy indoor environments, to integrating building systems for wastewater, heating, and other basic functions with existing ecosystems that perform those functions in nature. The domain of built facilities is ripe for implementing sustainability because not only are buildings vital to human existence in nearly all parts of the world, but also the built environment is one of the largest consumers of natural and manmade resources in the range of human endeavors. Built facilities also represent one of the most significant sources of negative impacts to the natural ecosystems on which we depend for life support. Traditional construction represents a profit-based approach to constructing the built environment, with minimization of cost as the primary objective, maximizing quality and performance as secondary objectives, and minimizing negative environmental and other sustainability-related impacts as a tertiary objective. The shift to a sustainable built environment does not necessarily eliminate these primary objectives of traditional construction, but rather embeds them in a larger context of sustainability-related objectives.

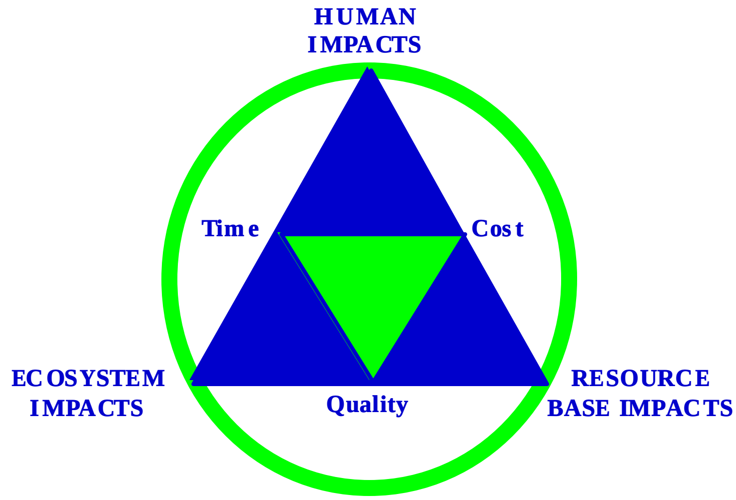

Figure 1: Parameters of Sustainable Facilities and Infrastructure (Pearce 1999)

The Importance of Sustainability for the Built Environment

Built facilities are complex technological systems that meet critical human needs, persist over significant lengths of time, and involve multiple diverse stakeholders. Their interrelations with the technological and ecological systems that surround them have significant impacts on those systems. These impacts have not always been noticeable on the scale of individual facilities, but their cumulative effects on the planet over time have been increasingly well documented. For example, buildings are responsible for over ten percent of the world's freshwater withdrawals, twenty-five percent of its wood harvest, and forty percent of its material and energy flows (Roodman & Lenssen 1995). 54% of U.S. energy consumption is directly or indirectly related to buildings and their construction (Loken et al. 1994). 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 (Kibert et al. 1994). Nearly one-quarter of all ozone-depleting chlorofluorocarbons (CFCs) are emitted by building air conditioners and the processes used to manufacture building materials (Energy Resource Center 1995). Approximately half of the CFCs produced around the world are used in buildings, refrigeration and air conditioning systems, fire extinguishing systems, and in certain insulation materials. In addition, half of the world's fossil fuel consumption is attributed to the servicing of buildings (Zeiher 1996). The average household is annually responsible for the production of 3,500 pounds of garbage, 450,000 gallons of wastewater, and 25,000 pounds of CO_2 along with smaller amounts of SO_2, NO_X, and heavy metals (Barnett and Browning 1995). Lighting accounts for 20-25% of the electricity used in the U.S. annually. Offices in the U.S. spend 30 to 40 cents of every dollar spent on energy for lighting, making it one of the most expensive and wasteful building features (Energy Resource Center 1995). Finally, the construction industry is responsible for 8-20% of the total Municipal Solid Waste (MSW) Stream, 14% on average (Tchobanoglous et al. 1993).

These cumulative impacts have resulted in increased attention to the role played by built facilities and infrastructure in the problems of natural resource depletion and degradation, waste generation and accumulation, and negative impacts to ecosystems. Since built facilities are a major direct and indirect contributor to these problems, they now face increasingly restrictive environmental conservation and protection laws and regulations, international standards to address environmental quality and performance, and substantial pressures from civic groups, environmental organizations, and citizens. As a result, facility stakeholders face new, complex and rapidly changing challenges imposed by these laws, regulations, standards, and pressures at all life cycle stages. Negative impacts to natural ecosystems have begun to enter into decision-making in the construction industry. Forced by environmental legislation such as the National Environmental Policy Act of 1970, many U.S. projects now require an Environmental Impact Assessment of the project to be completed before construction can proceed. Still, however, many project planners, designers, and contractors see environmental considerations as an obstacle to be overcome rather than a way to achieve benefits for themselves and others (Kinlaw 1992). Many actions taken to mitigate environmental impact of projects are typically only applied as end-of-the-pipe measures, not changes to the environmentally damaging processes themselves (Liddle 1994). These traditional strategies of mere environmental regulatory compliance or reactive, corrective actions such as mitigation or remediation have proven to be consistently costly, inefficient, and many times ineffective (Vanegas 1997).

Other drivers for change center around resource depletion and degradation. For example, many municipalities have adopted energy codes to promote energy efficiency in new facilities. While not widely enforced, these codes nonetheless represent an evolutionary step for the construction industry. In other cases, increased scarcity of resources such as dimensional lumber have forced the industry to seek alternatives to traditional materials, including engineered wood products, steel framing, recycled plastic lumber, and stress-skin panels. These products make use of materials formerly considered to be waste, including sawdust, post-consumer plastic, and wood pieces too small to be otherwise incorporated as structural members, and result in products that are structurally superior to the materials they replace. Alternative framing practices have also become more commonplace as constructors seek to minimize the use of raw materials. A positive side effect of some of these new trends is increased energy efficiency due to decreased thermal bridging and integrated insulation (BSC 1996).

A third driver for change is the increasingly noticeable impacts of the built environment on human health. Many humans spend most of their time indoors, nearly 90% of an average day (Kibert et al. 1994). Building-related threats to human health include the carcinogenic properties of asbestos and the neurologically damaging effects of lead-based paint. Yet these products were common components of buildings during the period between 1950 and 1970. More recent evidence supports the carcinogenic effect of low-level electromagnetic radiation, which is generated by all electrical appliances (Rousseau & Wasley 1997). Some individuals are highly sensitive to irritants and/or toxins such as off-gassed volatile organic compounds (VOCs), formaldehyde from adhesives and fabrics, and molds, bacteria, and dust accumulating in and resulting from building products (ibid.). The cleaning and maintenance products used during facility operation, including pesticides, solvents, and chlorine, present another set of irritants that cause reactions in an increasingly large portion of the population (ibid.). Given the complex combinations of materials and chemical products being incorporated into built facilities, the potential of buildings to have negative impacts on human health is significant. The number of potential irritants and toxins is growing rapidly with the proliferation of synthetic chemicals present in almost every product used by humans. Thus, threat to human health is a third significant category of drivers that reflects the need for change in the way built facilities are created and operated, along with the building technologies, systems, products, and materials used within them.

In response to these drivers of evolution, sustainability has emerged as guiding paradigm to create a new kind of built facility: one that meets the needs of humans in the present without limiting the ability of future generations to meet their own needs (after WCED 1987). At present, the industries responsible for the built environment are cost-driven, with minimization of first cost and implementation time as primary objectives, meeting quality and performance goals as secondary objectives, and minimizing negative impacts as a tertiary objective. The shift to a sustainable built environment does not necessarily eliminate these objectives of traditional construction, but rather embeds them in a larger context of sustainability-related life cycle objectives including minimizing negative impacts to resource bases and ecosystems while meeting the needs of system stakeholders.

To move toward sustainability, the Architecture/Engineering/Construction industry requires significant changes in the way it currently delivers facilities and civil infrastructure systems projects, and also, in the way manufacturers and vendors supply the building technologies, systems, products and materials it uses. Specifically, sustainability goals, concepts, principles, and guidelines need to be explicitly and systematically integrated in a project, at all stages of its life cycle, particularly the early funding allocation, planning and conceptual design phases. The challenges are: how can this be done? Where can one begin?

The Need for Continuing Education on Sustainable Facilities and Infrastructure

Georgia Tech's Sustainable Facilities and Infrastructure continuing education series was conceived as an alternative to the state of the art in sustainability information. While many conferences, workshops, and publications are now available that deal with built environment sustainability, few if any of these resources provide a whole systems perspective. Those that do consider whole systems generally fail to provide sufficient detail to permit practitioners to apply the concepts to their specific context. Further, stakeholders who seek a single resource spanning the range of sustainability issues from concept to technical details will find that no such resources currently exist. This series of courses is designed to fill these gaps with two significant sources of knowledge: 1) Georgia Tech's research-based knowledge of sustainability theory, integrated problem solving, and systems analysis; and 2) the lessons and knowledge-based expertise of professional practitioners.

Roadmap to the Sustainable Facilities and Infrastructure Continuing Education Series

Challenges of Achieving Sustainability for Built Facilities and Infrastructure

A number of challenges characterize the struggle to achieve sustainability in the built environment (Pearce 1999; Pearce et al. 2000):

- Lack of consensus on what sustainability means for the built environment
- Lack of understanding of how sub-concepts map onto the larger concept of sustainability (e.g., environmental management, compliance, "green")
- The difficulty of measuring sustainability, and the subsequent challenge of decision making for sustainable facilities
- Lack of understanding and myths associated with the economic impacts of sustainable building practices
- Difficulty in breaking out of traditional stakeholder roles and relationships; resistance to change
- Managing information overload in seeking innovative or nontraditional solutions and conversely, finding sufficient and reliable data on which to base decisions
- Finding effective and appropriate strategies to increase facility sustainability
- Integrating solutions for whole system optimization; overcoming traditional disciplinary barriers

To address these challenges, systematic and comprehensive approaches to training, education, and professional development are needed for built environment stakeholders. Continuing education of professional-level stakeholders in the built environment is one strategy for providing the necessary information and skill development to allow these stakeholders to become agents of change for sustainability.

Educational Desiderata for Sustainable Facilities & Infrastructure

An educational program to support achieving sustainability for facilities and infrastructure should include the following elements, each corresponding to the challenges and barriers listed in the previous section:

- A consistent, theory-based framework for understanding the concept of sustainability in terms of variables meaningful for built facilities and infrastructure
- A roadmap to understanding the relationships among sustainability and less comprehensive concepts such as "green", environmentally conscious, etc.
- A systematic and bounded process for problem definition and decision making that incorporates scientific and understandable methods for evaluating the sustainability of built facilities and their components

- A toolbox for evaluating the economic impacts of sustainable building alternatives and actions, including methods for clearly understanding those impacts in terms of the language of economics-driven decision making
- A set of operational strategies for proactively addressing resistance to change and the limitations of traditional stakeholder and organizational roles
- A structure for systematically identifying the kinds of information needed to sustainably solve built facility problems, and a means of obtaining and managing data to support the problem solving process
- An overview of the range of potential strategies, tools, technologies, and methods for increasing the sustainability of built facilities and infrastructure, presented according to project type and life cycle phase and including all information necessary to compare alternatives
- A pervasive theme of systems thinking to replace traditional reductionist analysis, incorporated into every other element of the educational program

These educational desiderata form the framework around which Georgia Tech's Sustainable Facilities and Infrastructure continuing education certificate series was developed.

Curriculum Design for Sustainable Facilities & Infrastructure

Georgia Tech's Sustainable Facilities and Infrastructure continuing education curriculum was designed to meet the need of built environment stakeholders who are seeking to make their facilities more sustainable. The curriculum meets the challenges of built environment sustainability by incorporating the elements of sustainability education described in the previous section. Figure 2 shows the basic structure of the SFI curriculum, beginning with *SFI 100: Primer for Sustainable Facilities and Infrastructure*, and continuing through the set of possible electives that may be taken to complete the continuing education certificate. Participants who pursue the certificate are required to take the first three courses in the series (*SFI 100: Primer, SFI 200: Assessment Tools and Techniques, and SFI 300: Economics of Sustainable Facilities and Infrastructure*). These courses are designed to provide a common basis of understanding of the concept of sustainability and the general analysis tools and methods useful to all built environment decision makers seeking to increase sustainability. SFI 100 serves as an overview course, and is appropriate for participants interested in taking only one course on built environment sustainability.

Following the three required courses, participants are required to take one of four discipline-specific courses that correspond to different phases of the project life cycle: design (SFI 410), construction (SFI 420), real estate development (SFI 430), and facility management, operations, and maintenance (SFI 440). Each of these courses is comprised of three primary parts:

- **Background, Teaming, Innovation, and Problem Solving**, in which participants learn how to break out of traditional project and discipline roles and methods;

- **Specific Strategies, Tools, Techniques, and Methods**, in which participants receive detailed information from industry experts on strategies that can be used to increase the sustainability of their facilities; and
- **Pulling the Pieces Together: Integrated Implementation**, in which participants learn how to select and integrate appropriate strategies for sustainability into an overall program for their facilities

The three required courses plus one discipline-specific course comprise a total of 64 hours of instruction, and meet the first half of the requirements for obtaining the Sustainable Facilities and Infrastructure Certificate. The second half of the certificate hour requirements must be met by taking 64 hours of electives relevant to sustainable facilities and infrastructure. A listing of existing and proposed courses that are valid electives for the SFI Certificate are listed at the end of this curriculum manual.

Target Audience

The built environment has a broad variety of stakeholder classes, both direct and indirect. Figure 3 shows a breakdown of typical stakeholders in terms of the life cycle of built facilities. To improve built environment sustainability, each class of stakeholders can benefit from education, training, and professional development focused on the topic. The degree of formal education, personal knowledge of sustainability, nature of job responsibilities or interaction with built facilities, etc., all determine the kinds of training that will most directly benefit each stakeholder. For example, the most effective strategy for encouraging sustainable behavior among building tenants may be simple awareness training on the effects of their everyday choices (e.g., to recycle or not, choices of lighting, etc.). In contrast, architects, engineers, and project managers involved in the design and delivery of a facility would probably find more technical and detailed focused professional development courses to be more useful in making their practices more sustainable. Likewise, a different level of training may be required for construction and maintenance labor, whose educational background may be minimal and who may not even be literate or fluent in the dominant language of the country in which they work. The main conclusion to be drawn from these examples is that sustainability education, training, and professional development should be appropriate to the audience and organizational context to which it is directed, and should address the kinds of issues, decisions, and practices faced by each stakeholder type in the audience.

Georgia Tech's SFI continuing education certificate series is targeted to stakeholders of the built environment who are interested in the concept of sustainability and how it can be applied to their facilities. Our audiences will include architects, engineers, contractors, builders, developers, planners, owners, and other professionals who are interested in the concept of sustainability as it applies to the built environment.

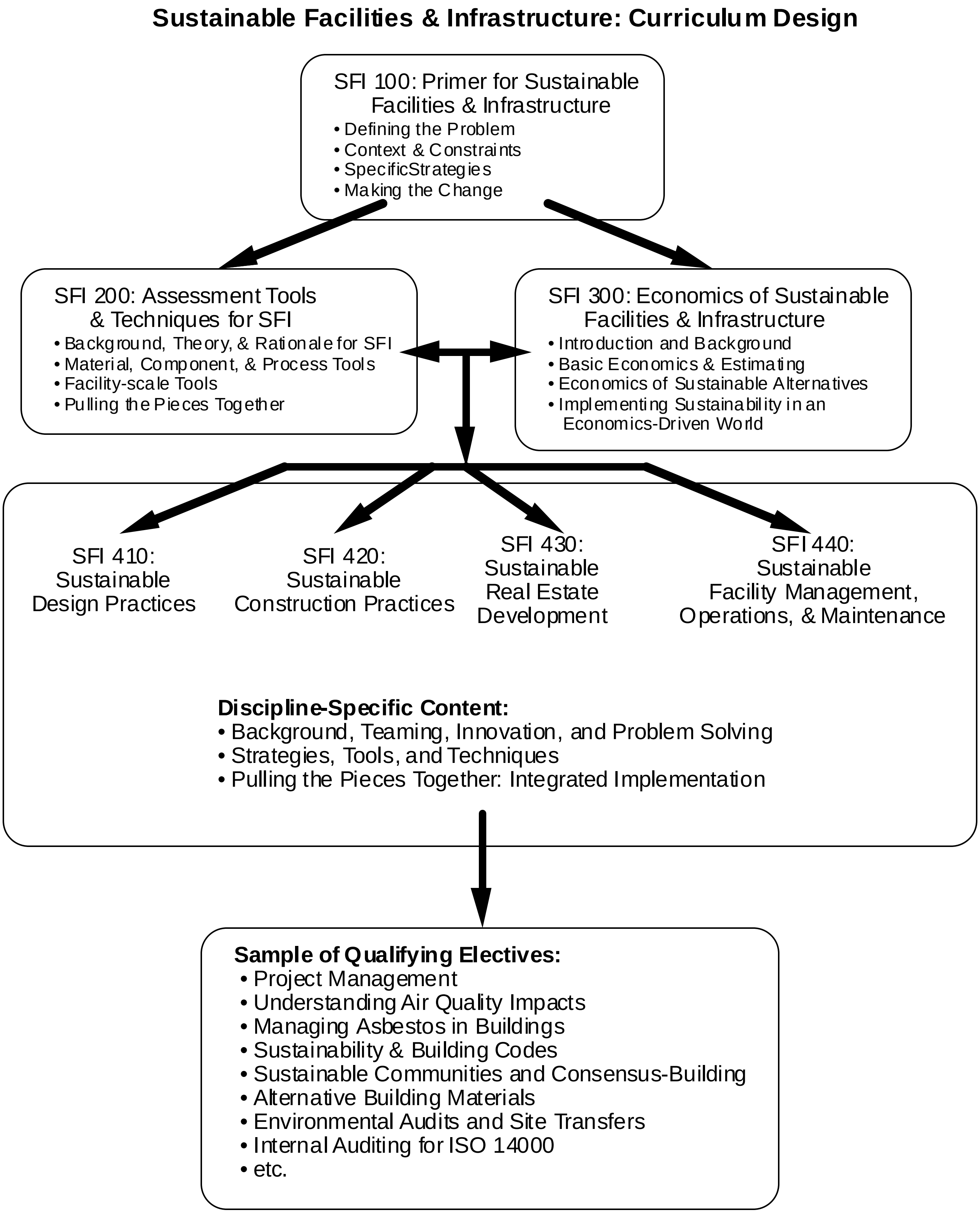

Figure 2: Structure of the SFI Curriculum

Learning Objectives of the Series

The overall learning objectives of the SFI Continuing Education Certificate Series are eight in number. Upon completion of the certificate series, course participants will be able to:

- Understand what sustainability means
- Understand how sustainability might benefit their enterprises
- Measure the sustainability of current and future projects
- Understand the economic costs and benefits of this new approach
- Work with diverse teams to make sustainability happen
- Use state-of-the-art tools and resources for analysis, design, and problem solving
- Prioritize potential strategies for improving project sustainability
- Apply specific strategies to their projects.

From the first primer course in sustainable facilities and infrastructure through the detailed, discipline-specific strategy courses and in-depth electives, each course in the SFI series provides an appropriate level of detail to meet these learning objectives in an integrated fashion. Participants will emerge from each course with a clear understanding of how to immediately apply the concepts covered in that course in their organizations and day-to-day professional responsibilities.

Benefits to Participants

Participants in Georgia Tech's Sustainable Facilities and Infrastructure continuing education certificate program will benefit in multiple ways from their attendance in the courses:

- Participants will tap into Georgia Tech's long-established and successful continuing education capabilities, including high-quality instruction on state-of-the-art topics
- Participants will receive sustainability instruction from a combination of Georgia Tech faculty who are experts in theoretical analysis methods, and expert practitioners from industry who use the techniques and technologies they teach in everyday practice

	External Stakeholders		Internal Stakeholders	
	Indirect	**Direct**	**Direct**	**Indirect**
PLANNING / PRE-DESIGN	Zoning Agencies Regulatory Agencies	Planners Developers	Owners Land Developers	Investors
DESIGN	Financiers Code Enforcement Agencies Manufacturers Professional Institutions Surrounding Communities	Design Team: • Architects • Engineers • Interior Designers • Landscape Architects Project Managers	Owners Land Developers	Investors Users / Tenants Facility Managers / Operators Clients / Product Consumers
CONSTRUCTION	Manufacturers Vendors / Suppliers Shippers Code Enforcement Agencies Regulatory Agencies	Construction Team: • Contractors • Consultants • Subs Utilities Financiers Project Managers Surrounding Communities	Owners	Investors Users / Tenants Facility Managers / Operators Clients Product Consumers
OPERATION / MAINTENANCE	Manufacturers Vendors / Suppliers Shippers Regulatory Agencies	Surrounding Communities Utilities Financiers	Owners Users / Tenants Facility Managers Operators Clients	Investors Product Consumers Users' Dependents
DECONSTRUCTION / DEMOLITION / DISPOSAL	Waste Disposal Companies Recycling Companies Regulatory Agencies	Surrounding Communities Demolition Contractor Disposal Agent Salvage Agents Developers	Owners	Future Users Investors

Figure 3: Built Environment Stakeholders by Life Cycle Phase (Pearce 1999)

- Participants will receive a course workbook loaded with useful references, comparisons of relevant software tools, speaker slides and content, and other information to support the real time application of sustainability concepts in their practices and organizations
- Participants will have the opportunity to test-drive the latest software packages for sustainable planning, analysis, and design using Georgia Tech's computing facilities
- Participants will have the opportunity to examine and review recommended books, manuals, material samples and literature, and other resources for facility sustainability
- Participants will have the opportunity to network with other practitioners in the class, both instructors and students, who are interested in applying sustainability to their projects
- Participants attending the courses are eligible for Georgia Tech continuing education credits, credit toward obtaining or maintaining Professional Engineer or American Institute of Architects certification, Real Estate licensing requirements, general contractor certification in the State of Florida, and lifelong learning tax credits where applicable

Reader's Guide to the Curriculum Manual

This manual provides an overview of the design of the series, the needs and implementation challenges it was designed to address, and its target audience. Following the introduction and roadmap to the manual, each course is presented first in overview form, then with an hour by hour agenda and module descriptions for each hour of instruction. The manual concludes with a list of candidate electives for obtaining a Sustainable Facilities and Infrastructure certificate, references, and appendices containing supporting material for the design and marketing of the first public offering of the series. Appendices include an overview of the marketing strategy, lists of speakers, continuing education topic and market surveys, a module developer's kit, and the official course brochure.