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Integrated Design and Delivery Process for Zero Net Energy Buildings

1. Introduction to Topic Area

This chapter addresses the Integrated Design (ID) process as a critically important approach to achieve cost-effective zero net energy building (ZNEB) projects. Although the discussion here is focused on buildings, true integration involves the whole project including site, campus, district, etc. Integrated design and an integrated building delivery apply to all aspects of project development from design and construction through occupancy. Given a zero net energy building will rely on the functional interdependency of a building's major passive and active elements, the aspects of integrated design and effective building delivery are critically important. This chapter provides background on the current status of integrated design and delivery practices related to energy, describes the barriers to application of integrated design, recommends best practices, and provides a set of actions for USDOE, the Consortium and other stakeholders to help accelerate the shift to wider use of the integrated design process. This chapter was prepared by members of the Integrated Design and Building Delivery Working Group (see Charter below) consisting of representatives of professional organizations and practitioners, non-government agencies, and industry (See appendix for Workgroup participants).

1.1 Charter

The Integrated Design and Building Delivery Working Group explores solutions to achieve zero net energy buildings that will align the design and delivery process among multiple stakeholders including owners and developers, construction industry (architects, engineers, builders, component suppliers), facility managers, maintenance and repair staff, and others to ensure buildings function as well-integrated wholes rather than a series of independent components. Solutions include team organization, design strategies, standardized Building Information Models (BIM), advanced computational tools and methods for dynamics, controls, commissioning, and post-occupancy operation and maintenance. Critical to these solutions is to reduce the time and increase quality to effectively design and deliver a zero net energy building that persists functionally during regular operation.

1.2 Problem statement

Over the last decade there has been a fair amount of frustration with traditional approaches to design and construction that remain sequential and segregated, constraining communication and cooperation among designers, builders, and occupants. The design and construction process is fragmented to the point that subcontractors are generally not aware of important building system interactions. As a result, building systems largely operate independently and sometimes against each other, resulting in inefficient use of energy. Driven by owner desire for lower costs and faster schedules, the design and construction industry is changing at a rapid pace transforming the building industry in fundamental ways, resulting in greater teamwork and increased efficiency in terms of work effort and eventual energy use.

Buildings that will be expected to deliver outstanding performance while consuming much lower amounts of energy—with zero net energy consumption the goal—will require more refined, integrated design and delivery processes than those in widespread use by the design and construction industries. Recent research[1] has shown that the level of integration has an impact on the level of sustainability that can be achieved.

Complex interactions lead to natural variance, yet as tolerances becoming tighter (e.g. lower infiltration, lower energy, etc), the natural variations become more significant. Inherent in this problem is the need for tools for addressing the complexity of major passive and active elements of buildings that affect energy in uncertain ways, as related to building location, orientation, thermal characteristics, and intended use.

1.3 Definition of Integrated Design (Conventional View)

Versions of integrated design have been in use since the 1950s and '60s. The movement for green, high performance and zero net energy buildings necessitates reforming and reinvigorating integrated design concepts and implementation.

Integrated design has typically been seen as the process by which multi-disciplinary building design teams form early and work together throughout the project schedule. Typically, these approaches are not aided by computational tools, nor organizing and scheduling tools. "Integration" is often used interchangeably with "collaboration", but such an interpretation leads to a fairly limited view of integrated design. Beyond collaboration is the integration of building envelope with building systems and integration among systems. The impacts of climate and building occupant scheduling and use must also be taken into account during the integrated design process.

The Whole Building Design Guide (WBDG) assembled by the National Institute of Building Sciences (NIBS) makes an important distinction between the two integration functions: there is an integrated design approach and an integrated team process. The emerging, more comprehensive view of ID is discussed below.

1.4 Definition of Integrated Design (Emerging View)

A more recent evolution of the concept and practice of integrated design relates specifically to energy efficiency and green building. To achieve significant levels of efficiency, and ultimately zero net energy, requires integration across all elements of the building, site, and environment including: structure, materials, systems, landscape, operations and occupant behavior. Furthermore, an emerging goal of ZNEBs is high quality design that fits within its community and context so they aren't ostracized as "just a NZEB" and people feel compelled to build them, not avoid them.

Integrated design and related integrative practices encompass the following dimensions:

- **all stakeholders** involved in defining building performance goals and engaged from the beginning in design problem-solving;
- **all building systems**, especially as they impact energy and water use, building performance, comfort, and safety;
- **the whole building life cycle**, from design and construction through operation to renovation and eventually demolition.
- **the whole project context** – site, campus, district, etc.
- increased use of computational, organizing, and scheduling tools.

[1] *Sustainable, High Performance Projects and Project Delivery Methods - A State-of-Practice Report. September 1, 2009, Research sponsored by the Charles Pankow Foundation and the Design-Build Institute of America (DBIA).*

A definition (or distinction) promoted by the BetterBricks program of the Northwest Energy Efficiency Alliance (NEEA) is that "integrated design is the synthesis of climate, use, loads, and systems resulting in a comfortable and productive environment and a building that is more energy-efficient than current best practices." According to Professor G. Z. Brown at the University of Oregon School of Architecture, "the fundamental process of integrated design is the search for synergies. Synergistic strategies create benefits greater than the sum of the individual design decisions."

These practices engage architects, engineers, builders, component suppliers, owners, and facilities operators in collaborative design, construction, and operation. To achieve the full benefits of these practices requires changes in AEC business models, contracting, fee structures, risk/reward, insurance, organizational culture, and much greater collaboration across a building industry supply chain that remains fragmented and siloed.

2. Background

2.1 Conventional Practice

The 7group and Bill Reed, in *The Integrative Design Guide to Green Building: Redefining the Practice of Sustainability* describe current practice as "Siloed Optimization". In brief:

> *The architect meets with the owner to discuss the program, which determines the size, function, and adjacencies of required spaces. These fundamentals inform an iterative schematic design process that, when complete, is distributed to the remaining members of the design team, who, in isolation, endeavor to provide optimal designs for the individual systems that are each of their responsibilities. These separate designs are compiled by the architect into a final set of project design documents, which are used to prepare budget estimates. The estimation process, generally suggesting a project that is over budget, leads to a value engineering process that cuts out pieces, reduces scope, and eliminates enhancements, all to deliver a project that appears to be within budget. A final set of construction documents is then sent out to construction professionals who, in a very short period of time, are expected to place a firm price on delivery of the proposed project. "Then, we select the lowest bidder, which essentially means that we end up awarding the construction contract to the team that understands the project the least."*

2.2 Emerging ID Approaches and Initiatives

Suggestions about how integration of formerly *siloed* activities and processes can enhance both design and project delivery are widely available. Yet, it remains surprising how often the delivery process is addressed as a way to increase productivity and reduce waste, without also considering how the design process must be rethought in order to generate design solutions that greatly increase building energy performance.
The following resources vary in their emphasis upon integrated design and integrated project delivery. Each of them provides useful materials to professionals and practitioners interested in modifying their own practices. Only recently has there been an effort to standardize aspects of integrated design (see ANSI Standard for Whole System Integration Process below). It is important to remember that while some progress is being made, both design and

project delivery practices need to further evolve to enable the design and construction industries to deliver consistently high performing and zero net energy buildings.

2.2.1 A Systems Approach

7group and Bill Reed, in *The Integrative Design Guide to Green Building*, introduce a "systems approach" to (re)define sustainability. Their recommended design process places a building within a broad context of environmental systems and their holistic model extends from building design, through project development, construction, occupancy and use. Practical steps to manage an iterative design process are offered and detailed methodologies are suggested that can be used by a design team to regularly check the evolution of a design against original documentation of design intent and purpose. During the development of this process and preparing the book, the writers became involved in an effort to standardize the process. This recently became the ANSI standard described below.

2.2.2 Integrative Design - A National Standard

The ANSI/MTS 1.0 Whole Systems Integrated Process Guide (WSIP)-2007 for Sustainable Buildings & Communities is the first attempt at standardizing the integrated design process. It focuses on the team structure and collaboration strategies. Through ANSI's required national consensus process, the Institute for Market Transformation to Sustainability led a broad team through the steps to arrive at the new ANSI standard. The ANSI website states that this "Standard Guide supports the building industry in the practice of integrative design. The purpose of Integrative Design is to effectively manage the optimization of complex systems while pursuing sustainable practices in design and construction. To achieve cost effective and increasingly more effective environmental performance, it is necessary to shift from conventional linear design and delivery processes to the practice of interrelated systems integration."

2.2.3 LEED Recommended Approach

The LEED rating system of the US Green Building Council technical guidance facilitates and encourages project teams to use an integrated design approach from start to finish, "bringing down overall costs and delivering project goals" according to USGBC. LEED points now consider the degree to which the building design utilized an integrated design process. Using this integrated approach, LEED promotes improved practices in:

1. Site selection and development.
2. Water and energy use.
3. Environmentally preferred materials, finishes, and furnishings.
4. Waste stream management.
5. Indoor air quality and occupant comfort.
6. Innovation in sustainable design and construction.

The current draft of LEED for Healthcare proposes an ID credit, based on the existing prerequisite of the Green Guide for Health.

2.2.4 Optimization through Synthesis

The BetterBricks initiative of the Northwest Energy Efficiency Alliance has been promoting an approach to integrated design for energy efficiency, built upon the work of the University of Oregon's G.Z. Brown, which focuses upon opportunities for extremely high levels of energy performance that emerge from a framework, or method, that encourages the exploration of opportunities to synthesize project-specific design solutions from structured

consideration of climate, building occupancy and use, the loads created by aspects of building and site design, and the selection, sizing and operation of passive and active building systems.
(See http://betterbricks.com/track.aspx?link=graphics/assets/documents/IED-Rethinking_Design.pdf)

2.2.5 Integrated Design Strategies and Prototypes: ASHRAE Advanced Energy Design Guidelines

The next round of ASHRAE Advanced Energy Design Guides will provide recommendations to achieve 50 percent energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 for commercial buildings of a particular type and size. (An earlier set of six guides had been developed to provide recommendations resulting in 30 percent savings from a 90.1-1999 baseline.) The first guide, intended for small to medium office buildings is in concept draft form, as of September 2010. This draft incorporates a number of integrated design strategies and offers recommendations regarding the architectural design of the building or that address envelope, lighting HVAC systems and service water heating energy conservation measures. The analysis used to prepare these design guides includes the development of prototype buildings and the simulation of energy use in different climate zones across many design configurations and application of a variety of energy conservation measures. Following publication of these guides, ASHRAE plans to develop zero net energy guides.

2.2.6 Integrated Project Delivery

The American Institute of Architects (AIA) national organization has been active in developing models of integration and enhancing the ability of project teams to produce higher performing buildings. *Integrated Project Delivery: A Guide (Version 1, 2007)* discusses desired outcomes and primary responsibilities of project team members at each phase of the design and development process.

Design phases have been redefined as: Conceptualization (expanded Programming); Criteria Design (expanded Schematic Design); Detailed Design (expanded Design Development); Implementation Documents (Construction Documents); Agency Review/Permitting; Buyout; Construction (Construction/Construction Administration); and Closeout.

The use of various multi-party agreements is discussed, each with the following common attributes: parties bound together by a single agreement or an umbrella agreement creating a temporary organization and defining management and decision making processes; processes tailored to support a team environment; decisions arrived at through consensus, with “best for project” outcomes; some portion of compensation tied to project, not individual success; and roles assigned to the person or entity best capable of performing them.

The contract models needed to support new teaming approaches has been further refined by The National Association of State Facilities Administrators (NASFA), Construction Owners Association of America (COAA), The Association of Higher Education Facilities Officers; Associated General Contractors of America (AGC) and American Institute of Architects (AIA), who have collaborated to produce *Integrated Project Delivery for Public and Private*

Owners[2]. This publication considers three Levels of Collaboration and explores both the philosophy of integrated project delivery and the contractual approaches to support different project delivery methods. Forces for industry change are considered, including: concerns about construction industry waste and lack of productivity, evolving software tools for design and construction, and owner demand for value. Addressed to owners, this document focuses upon contractual models and team management, without spending much time on the changing scope of professional services that might need to be addressed during different phases of design.

The following table excerpted from *Integrated Project Delivery: A Guide* (2007, AIA national and AIA California Council) summarizes some of the ways in which IPD differs from traditional project delivery.

Traditional Project Delivery		**Integrated Project Delivery**
Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled	**Teams**	*An integrated team entity composed of key project stakeholders, assembled early in the process, open, collaborative*
Linear, distinct, segregated; knowledge gathered "just-as-needed;" information hoarded; silos of knowledge and expertise	**Process**	*Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect*
Individually managed, transferred to the greatest extent possible	**Risk**	*Collectively managed, appropriately shared*
Individually pursued; minimum effort for maximum return; (usually) first-cost based	**Compensation / Reward**	*Team success tied to project success; value-based*
Paper-based, 2 dimensional; analog	**Communications / Technology**	*Digitally based, virtual; Building Information Modeling (3, 4 and 5 dimensional)*
Encourage unilateral effort; allocate and transfer risk; no sharing	**Agreements**	*Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing*

2.2.7 The Whole Building Design Guide

The Whole Building Design Guide http://www.wbdg.org/ is a web-based portal, developed by the National Institute of Building Sciences, as a gateway to information supporting integrated design. Organized into three major categories—Design Guidance, Project Management, Operations & Maintenance—the site is a resource for design guidelines, technology information, and summary discussions on a broad range of topics.

2.2.8 Federal Executive Order

An October 5, 2009 Executive Order requires federal agencies to implement high performance sustainable Federal building design, construction, operation and management, maintenance, and deconstruction. Beginning in 2020 and thereafter, all new Federal buildings that enter the planning process will be designed to achieve zero-net-energy by 2030. In addition, all new

[2] Prepared by The National Association of State Facilities Administrators (NASFA), Construction Owners Association of America (COAA), The Association of Higher Education Facilities Officers; Associated General Contractors of America (AGC) and American Institute of Architects (AIA), 2010.

construction, major renovation, or repair and alteration of Federal buildings complies with the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* (Guiding Principles).

The Guiding Principles define a collaborative, integrated planning and design process that initiates and maintains an integrated project team in all stages of a project's planning and delivery; establishes performance goals for siting, energy, water, materials, and indoor environmental quality, along with comprehensive design goals; and ensures incorporation of these goals throughout the design and life cycle of the building; and, considers all stages of the buildings lifecycle, including deconstruction.

2.2.8 Utility Programs

Several states, municipalities and utilities offer financial incentive programs for buildings that are designed to perform better than current energy codes. A list of financial incentives offered by various governments and organizations can be found at http://www.dsireusa.org/

A number of utilities offer Whole Building programs that contain guidelines on integrated design, including Alliant Energy, California utilities (Savings By Design program), the Energy Trust of Oregon, Excel, MidAmerican Energy Company, and NYSERDA. At a minimum, these programs have prescribed processes for looking at the energy ramifications of design decisions.

2.2.9 Enabling Tools and Technologies

Tools are evolving to support integrated design. The ability to easily model external and internal environments allows architects and engineers to explore multiple alternatives early enough to make suitable choices that maximize energy efficiency at low or no incremental cost.

Building Information Modeling (BIM) is a further evolution of CAD tools and performance simulation and constructability testing. BIM supports and facilitates integrated design by providing a common frame of reference, an easily updated shared information repository, detailed drawings and other construction documents, and visualizations of a building during all phases of its life cycle. With the combination of BIM and ID, the team of owners, architects, engineers, builders, and facility managers and operators has a software platform to support collaboration from the beginning of a project.

BIM support for integrative practices includes:

- virtual building models with intelligent building objects, 3D visualization, and 4D animations linking building elements to construction schedules
- analyses of energy use, daylighting, and computational fluid dynamics
- detailed estimates for both first cost and facility's ongoing operations
- the ability to do clash detection (e.g. conflicts between pipes and ducts with the structure) in the virtual model prior to construction
- project management across the entire design and construction process
- collaborative work with teams 24/7 in all locations, including construction sites
- computer-aided manufacturing (CAM) and off-site fabrication
- intelligent building controls.

The greatest benefits of these tools will come when interoperability standards enable their widespread interconnection and integration over the next 5-10 years.

2.3 Key Actors and Organizations

A number of organizations are actively engaged in advancing the market shift to integrated design – either conducting research, working to provide better definitions of practice, promoting new practices, developing tools, developing contracts and business strategies, and demonstrating its effectiveness. A partial list of organizations leading the way is contained in the Appendix.

3. Barriers

This section describes the significant barriers to more widespread use of integrated design. Some of these barriers are physical or structural and some are perceived. The Best Practices section (Section 4) addresses actions project team members can take to overcome some of these barriers and the Action Items (Section 5) proposes further work to resolve other barriers.

According to the New Buildings Institute (NBI), "The barriers to the widespread design and construction of low-energy buildings are not technical in nature, nor do they appear to be financial; more likely they are related to the motivation of owners and the skill set of the design and construction teams." NBI continues, "Currently, there is limited practical guidance for design teams who may be ready to consider improvements to performance which would make their buildings 50% or more efficient than code. The uncertainties and time requirements of researching and implementing new approaches, and the associated performance risks, continue to be real-world obstacles to improved energy performance."

In general, the major barriers are ignorance and a lack of examples, effective analysis and design tools, a lack of expertise on how to integrate systems, and performance feedback. These and other barriers are discussed below.

3.1 Definition and Standard of Practice

The effort to redefine integrated design and integrated project delivery as a "new" practice has resulted in two barriers:

- There is a lack of a commonly accepted definition or practice. Instead, there is an ever growing number of definitions and approaches under the umbrella of "integrated design".
- It has met a certain amount of skepticism and resistance. It has been argued that architects and general contractors have always integrated the work of others and that it is a fundamental part of what they both do. Furthermore, efforts to define integrated design practices have been under way for a generation or more, and those in the industry with long memories, who are now in senior positions in their firms, often respond to current integrated design initiatives as if they are hearing the same old refrain.

3.2 Market Structure Issues

- GreenBiz editor and clean energy consultant Joel Makower concludes: "The complexity of interaction among the participants is one of the greatest barriers to energy-efficient buildings."
- While the design and construction process places architecture and engineering firms in a position of significant influence, owners and their agents remain the principal decision-makers but these decision-makers are generally unaware of the attributes of energy-efficient buildings, how these attributes align with their business interests, or how to

obtain a higher performance building (e.g. what to ask for, the process to get it (ID) and how to evaluate it).
- Developers are frequently speculative, which inevitably results in a short-term investment horizon.
- Split-incentives: When developers plan to hold on to property to secure an income stream, they don't typically benefit directly from energy-efficiency measures, as energy cost savings go to the occupants who pay the bills, even though the developer incurs the investment cost.
- Given inherent business pressures to minimize time and expense, A&E firms have limited opportunities to apply integrated design and advanced design practices, and limited time for research and advanced training. As a result, commitments to pursue integrated design and integrated project delivery need to be made by firms independently from activities related to individual projects. Capabilities need to be assessed and enhanced, internal design and project management practices need to adjusted, and appropriate teaming relationships need to be established before a project is begun, Few, if any, projects have budgets and schedules generous enough to allow these actions to be implemented on a project-specific basis.

3.3 Market Inertia
- The biggest barrier to adopting ID is probably the issue of organizational practice and culture. ID requires new ways of thinking, working, collaborating, and new leadership. Issues needing resolution include:
    - Who is most capable of implementing new design and delivery processes – the owner, the designer, or the building contractor
    - Financing, legal contracting, liability, and insurance issues
    - Acceptance of shared risk and reward among designers, contractors, and owners
    - New fee structures that accommodate more design work at the front end even though costs may be the same overall or less because mistakes are caught early and change orders are significantly lessened.
- Most buyers of construction services know that the easiest way to differentiate proposals is via cost. So many other measurements are subjective in nature that it takes a significant amount of expertise to decipher the varied responses that can come from a request for proposal (RFP).
- There is low motivation or rationale to do anything different due to low awareness among owners, developers, and tenants that buildings are the top cause of carbon emissions.

3.4 Budget and Cost
Since there are few examples of zero net energy buildings, there is limited evidence of cost impacts. However, there are some indicators of cost issues.
- Turner Construction's 2005 *Green Building Market Barometer* survey of construction and real estate industry executives revealed that 68% said they avoided green construction because of concerns about cost. They also said lack of awareness and information about financial benefits deterred them. However, Turner's 2008 *Green Building Market Barometer* found 84% of respondents citing lower energy costs in green buildings; 68% note overall operating cost savings; 72% say green creates higher building values, all motivators to a continued increase in green construction across all market sectors.
- The World Business Council for Sustainable Development's Energy Efficiency in Buildings (EEB) initiative's 2007 global survey in six countries "found that perceptions

of the cost necessary to achieve greener buildings are likely to be significantly higher than the actual cost. The average perception was a 17% premium, but cost studies on actual properties have shown much lower figures.

- With an emphasis on costs, the Design-Bid-Build lump sum delivery offers a known first cost on a project. Any other delivery method means that the cost might not be known until sometime later in the project.

3.5 Perception of Value - the Business Case

- Quality, in the built environment, has too often been defined in very narrow terms: the ability to meet the performance criteria of a set of standards and codes. Value is primarily determined by financial criteria that might be applied, with slight modification, to any set of investments and assets. A business case for high performing zero net energy buildings needs to add the strategic dimensions of how facilities can directly support organizational goals and objectives and how a broad array of factors related to facility performance impact societal well being. Arguably, the later is the key factor or driver in net-zero energy buildings.

3.6 Regulatory

- Regulations established to ensure public safety and health often serve as impediments to the adoption of new technologies and design solutions. While some jurisdictions have recognized this situation and are beginning to allow some innovation, on a trial basis, local code officials sometimes remain constrained by state codes. The political dimension of the code revision process is often responsible for slowing or blocking the ability to bring about change.
- Energy codes generally offer both prescriptive and performance based compliance paths but the majority of projects have historically pursued the simpler prescriptive option. Projects using an integrated design approach to achieve higher levels of efficiency will require regulatory review of more sophisticated designs, some of which are harder to model and harder to review. More sophisticated code review capabilities will be required, a potentially significant barrier in jurisdictions without ready access to these capabilities. Even in jurisdictions with the needed capabilities, the time required to review more sophisticated designs will extend the time required for regulatory approval. Finally, time and capacity often drive a regulating official to make cursory evaluation of a building's energy compliance, prioritizing instead the structural and safety aspects of the design and delivery stages. Many states allow regulators to "opt out" of the non-critical design elements if resources restrict them from doing so.
- Energy codes don't address all elements of the design that contribute to the lower energy use, for example plug loads aren't regulated but they become a dominant load once the building envelope and major systems attain higher levels of efficiency.
- Other specific regulatory barriers exist that make it difficult to use certain strategies such as reducing air flow rates in hospitals or labs.

3.7 Contractual

- The design and construction industries generally do business through modified standard sets of contracts. Common contract forms make it difficult to implement integrated design. New ways of doing business will require new, standard contract documents.
- The use of various multi-party agreements is needed, each with the following common attributes: parties bound together by a single agreement or an umbrella agreement creating a temporary organization and defining management and decision making processes; processes tailored to support a team environment; decisions arrived at through consensus, with "best for project" outcomes; some portion of compensation tied to project, not individual success; and roles assigned to the person or entity best capable of performing them. The AIA has released a family of IPD documents that address the changes in the way projects are delivered. In addition, the AGC has released Consensus documents and other organizations like the DBIA are working on similar documents.

3.8 Capacity (Skills of Team Members)

- Pursuit of integrated design solutions requires new skills from the project team. For example, analysis and disaggregation of the various factors contributing to building loads will allow quick ranking of opportunities to increase performance; real time modeling capabilities to evaluate the likely impacts of design solutions (during team meetings); familiarity with specialized performance modeling methodologies applied to systems and equipment (e.g. optimization of duct and piping systems); up-to-date experience with higher performing systems and newer technologies; experience with measurement and verification planning and implementation and an awareness of O&M needs will all be required. In addition, the ability to work collaboratively is essential. All of these skills require training either through courses or direct experience. Although some of this is now being taught in architecture and engineering schools, design professionals that have been out of school for more than 5 years will need special training.

3.9 Schedule and time

- Typical project timelines and phases will support integrated design, but the amount of time devoted to different project phases will change. Virtually all members of the project team will shift hours to earlier in the project development phases. This additional time devoted to programming, conceptual design, schematic design, and design development will generally save time during later project phases. Nonetheless, there is resistance to paying higher fees to the team earlier than owners are accustomed to and many consultants are not used to working in earlier phases of design.

3.10 Tools and Processes

- BIM is not yet mainstream in the AEC industry. However, well over half of the larger architecture firms have acquired BIM capability. As examples, HOK committed to using BIM in all new projects and NBBJ has over 75% of its projects using BIM. The GSA now requires BIM for all major projects (prospectus-level) receiving design funding. The relevant barrier to zero net energy buildings is the lack of an easy, accurate energy performance modeling interface that can be used to link performance simulation to early design decision-making. BIM systems are not yet fully interoperable or standardized. Consultants working on a project may use different BIM systems with different file formats. Industry and professional organizations, including the National BIM Standards Committee of the National Building Sciences Institute, and the International Alliance for Interoperability are working on these issues.
- There is a steep learning curve in going from CAD to BIM requiring a different way of thinking, as well as learning new technology platforms.
- While BIM is particularly valuable for complex building types, there is a lack of easy and effective analysis tools for smaller less complex buildings.
- More work is needed on collaborative information and communications technologies like web conferencing, virtual team rooms, etc.
- More understanding is needed on the computational toolset in terms of open sourcing, proprietary interfaces, seamless functionality, and user interfaces. Further, there are limitations in the computational toolsets on addressing design uncertainties, delivery risks, inherent dynamics, and control design.

- There is a lack of tools that allow the design aspect and intent to be managed through the whole delivery process – including code compliance, operational impact, and ultimately maintaining the energy design goals.
- Energy modeling is too often used as a check on how well a design has done rather than a decision making tool.

3.12 Information Availability, Appropriateness and Timing

Integrated design requires both analysis and synthesis and a project's analytical needs mean that climate data, benchmarking resources, cost assumptions, etc. are all needed early in the design process to inform decision making. Team members need guidance regarding the analytical scope required to support higher levels of performance and assignments need to be made to the most appropriate team members. One example from BetterBricks is guidance for architects to use with engineers on energy engineering and performance modeling that suggests analytical steps to follow based on the integrated design process.

4. Best Practices

This section discusses things for architects, engineers and owners to do for successful application of ID to achieve zero net energy buildings. Integrated design experience has produced some guidelines and recommendations for effective implementation. Additional information about these Best Practices can be accessed in the reference documents listed at the end of this chapter.

4.1 Practices for Teams to Consider Now

4.1.1 Early Lessons Learned

The following are lessons that are excerpted from a recent multi-party report[3] based on a true Integrated Project Delivery (IPD) contract for deep collaboration.

- *Team behavior is crucial for a successful IPD project*. Everyone must be willing to participate and operate as a unified team. Trust is essential to a strong team.
- *Clear communication is necessary.* As more essential team meetings and collaboration take place, there is still a need to establish reporting mechanisms and document decisions.
- *A scoping exercise should be conducted at the beginning of the project*. It is beneficial to the project for the team to confirm that the project will meet all of the expected needs. Some IPD participants believe the team should agree on a scope document and include it as part of the contract.
- *Validation and optimization should be a continuous effort throughout the design,* in order to eliminate Value Engineering at the end of design. Coordination is an on-going process with all parties involved early. For example, the permitting process and pricing can be sequenced as the project proceeds.
- *A BIM Execution Plan (BEP) should be completed at the start of the project* for model sharing among all team members. BIM is successful in an IPD environment if the design and construction team shares one BIM model. The BIMs should be easily accessible in the field office. There is a steep learning curve in going from CAD to BIM. It requires a different way of thinking, as well as learning new technology platforms. Extensive

[3] Integrated Project Delivery for Public and Private Owners, NASFA, COAA, APPA, AGC, AIA, 2010.

training, on-demand support, and informal user communities sharing problems and solutions all help ease the challenge.

- *Early involvement of trade contractors and suppliers is beneficial to the project*. It allows the team to design what will be built instead of designing for intent, saving time and money. It is best for key subcontractors to be part of the IPD contract. Determine a method to incorporate smaller subcontractors (such as glass, ceilings, security) for consistent project goals.
- *An Independent Judge is sometimes used in determining how well the team met the project goals*. The judge, agreed on by the three primary parties, is brought in at project completion to assess design quality.

4.1.2 Data needs for charette effectiveness

The effectiveness of early design charrettes and workshops is greatly increased when a certain amount of analysis is performed prior to the workshop. Programming and functional space planning should be documented before the charrette. Climate analysis can be completed. Simple “shoe box” energy simulation models should be run to inform discussion of building and site design and consideration of HVAC system options. Benchmarking resources relevant to the region and the building type should be available to support energy performance goal setting.

4.1.3 Effective Hand-off Procedures From Design to Occupancy

To ensure extremely low levels of energy consumption, it is necessary to link design, construction, start-up, and occupancy activities to the same energy performance goals and objectives. Green building rating systems have helped the design and construction industries begin to more regularly link energy goal setting and the design process and to employ commissioning to ensure congruence between design and construction, but additional focus is required to establish similar performance responsibilities with building occupants and O&M service providers.

Clear, understandable documents need to be prepared by the project team to ensure that building occupants, facilities staff, and contract service providers all understand operating protocols required to ensure building performance. Appropriate education/training needs to be provided to ensure that the protocols are understood. A certain amount of ongoing support may be required during the building warranty period and on an ongoing basis.

One model of how these linkages might be made is being explored by the USGBC, in considering better integration between LEED new construction and existing building rating systems, to address the entire building lifecycle. Also, LEED points now consider the degree to which the building design utilized an integrated design process.

4.1.4 The Role of Operators and Occupants

At the highest levels of energy performance, and certainly at net-zero, building occupants, operators, and service providers need to take an active role in delivering performance. They need to be engaged at the very start of pre-design discussions for the setting of performance goals and to explore the implications of schedules, establishing the bounds of comfort criteria, and considering the performance implications of individual (and collective) control of lighting and HVAC systems (whether automatic or manual). Occupants and facility staff need to be fully informed about how their actions can enhance or degrade performance and some mechanism (e.g. lease clause) is needed for them to share the responsibility for performance. Appropriate contract models will also need to be in place with third-party service providers. Performance based contracts should be considered.

The degree to which a building utilizes a comprehensive building management system must also be considered relative to the operator and occupants. Building management systems that are incorporated into an integrated design earlier in the process are more likely to consider advanced controls and dynamic considerations of the building that can be carried through the commissioning process. Defined control points, operational boundaries, dynamic control stabilization, natural variance and occupancy requirements are all aspects that point to the need for earlier entry of the control team into the design process. (Note: the New York Times building lighting management system designed jointly with Lawrence Berkeley National Labs is a good example to consider).

4.1.6 Pilot Projects and Demonstrations

There is a shortage of well documented real-world examples of low energy buildings and the integrated design strategies they employed. The team should commit to documenting design process, solutions and outcomes and commit to making them available publically, or at least to DOE.

4.2 Longer-Term Best Practices

4.2.1 Standards for ID for ZEB

Currently there are several “standards” for integrated design – one for Integrative Design (or Whole system Integration Process, an ANSI standard and other documented “guidance” such as the Whole Building Design Guide section on Integrated Design, USGBC’s recommendations in the Technical Reference Guide and, New Building Institute’s Core Performance manual. These all differ to some degree, illustrating the need for a core set of defined standardized practices required to achieve zero net energy buildings.

4.2.2 Mechanisms to Overcome Obstacles to Feedback Loop Information

Tools and practices are needed that can integrate design, construction, commissioning and operation into a more coherent process and enable it to be iterative. These tools must take advantage of advances in communications technology to enable stakeholders involved in all phases of the building lifecycle to interact and cooperate and should also enable an optimal transition between the design, construction, commissioning and operations phases. It is possible that much of this need can be met by more widespread use of construction management and facilities management software.

4.2.3 M&V and POE

Performance measurement and verification (M&V) should be universally expected of high performance buildings. It may remain difficult to evaluate particular integrated design strategies because of the need to evaluate performance on a whole building basis, so it will be essential that M&V efforts delve deeply enough into any performance shortfalls to assess the reasons for variance and to propose measurable action items to resolve poor performance. This will be of particular concern with performance-based contracts or IPD contracts with commitments to performance levels.

More widespread use of Post Occupancy Evaluations (POE) will help document the benefits of high performance, by documenting environmental conditions and assessing occupant satisfaction.

4.2.4 Multi-party Agreements to Commit to Timeline and Responsibility for Performance
Multi-party agreements are a key method to ensure all members of the team are committed and share equal responsibility for a project's performance targets. For background information and as general references, see: *Integrated Project Delivery for Public and Private Owners,* and *Integrated Project Delivery: A Guide (Version 1, 2001).* For standard contract documents, see the AIA Integrated Project Delivery (IPD) Family of documents http://www.aia.org/contractdocs/AIAS076706.

4.2.5 Funding and Incentives
Design teams should seek out and take advantage of financial incentives. Some utilities offer incentives based upon the simulated energy performance of whole-building design efficiency as well as support for parts of the process such as modeling or commissioning. These incentives will support a project focus on energy performance. There are federal tax deductions and credits and some state tax credits. A list of financial incentives offered by various governments and organizations can be found at http://www.dsireusa.org/.

5. Actions Required

The Working Group has identified actions key stakeholder organizations should take to quickly move the market (i.e. market transforming strategies). There are market-focused actions and technically-focused actions.

5.1 Actions by DOE

5.1.1 Market-Focused Recommendations

Frustration with traditional approaches to design and construction, as well as increased interest in energy efficiency and sustainability, represent an opportunity to accelerate the change and insert improved integrated design practices, tools, products, and services into the market. There is a need to build awareness of the value of ID, of standardized processes, and roles of participants. The following sets of strategies are organized by the categories of architects and engineers (A&E) as well as owners.

- Architects - Design: The notion of what is an aesthetically good building needs to change (e.g. (e.g. not all glass on all sides of the building, or bristling with green technology that doesn't fit the building or its surroundings).
- A&E - Technical: Provide information, tools, training and project specific support to architecture and engineering firms committed to promoting energy-efficient, high performance buildings.
- A&E - Technical: Develop and/or refine specific tools for applying integrated energy design strategies, such as lighting analysis tools, natural ventilation analysis tools, and schematic phase energy modeling.
- Owners: Provide information, tools, training and support to owners, developers and their agents involved in new construction activities. Help build owner capabilities to specifically ask designers and builders for integrated design services resulting in high performance buildings. Provide case-based documentation of real world success and project specific support to demonstrate technical viability and validate the benefits from changing design and construction business practices.
- All: Influence and leverage professional development curriculum and training opportunities offered by the American Institute of Architects (AIA), the Urban Land

Institute (ULI), the U.S. Green Building Council (LEED) and others with complementary training and education agendas.

- All: Develop low-cost post-occupancy assessments tools for review and evaluation of design strategies, building performance and owner/occupant satisfaction.
- While DOE is developing a central clearinghouse, one aspect that is needed is a standardized format for case studies and data presentation and an easy way to find these case studies. Many case studies are ineffective at reporting energy performance, either by not providing much detail, only reporting estimated savings, or by not providing specific reasons that a project might under-perform. One solution might be to have third-party development or third-party review of case studies. Since case studies are not inexpensive, incentives to develop case studies might be helpful.

5.1.2 Technical-Focused Recommendations

- Research is needed on metering and monitoring equipment; and real-time system integration.
- Software development and enhancements for modeling and simulation, as well as analytic techniques and design guidelines and design decision tools. While energy modeling software (e.g., Energy Plus, DOE-2, and packages for VisualSPARK or Modelica) offers the ability to model many types of building energy demands and production, representing a given building design in the proper input format can be challenging.
- Advancements in integrating Building Information Modeling (BIM) with simulation tools is critical to increase the role energy modeling can play during building design. Provide support to strengthen the reliability, consistency, and usability of predicted energy use and energy cost results. The goal is complete and accurate energy estimates earlier in the design process along with improved life-cycle costing analysis. Develop a flexible interface for EnergyPlus to provide a robust mapping from BIMs to EnergyPlus that supports a broad range of design development and incremental detailing procedures.
- Develop and deploy a zero net energy design computational methodology and the use of high performance computation focused on the creation of computational fundamentals with attention to dynamics & control.
- Tools need to be developed that can assist zero energy design teams, broadly defined, in revealing system dynamics to enable delivery of passive systems at reasonable cost and risk.
- Conduct cross-cutting integration between energy efficiency technology research efforts at the different USDOE supported national labs to seek potential synergies supporting integrated design technical solutions, particularly related to controls and system and equipment interactive effects.
- Coordinate E-RIC Hub efforts with other efforts around the country at universities and national labs.

5.1.3 Codes, Standards and Enforcement Support

Over time, the evolution of energy codes will push the market toward higher levels of energy performance. National support is needed (similar to what NEEA does in the PNW) to support such advances. This support needs to include educational campaigns, lobbying, education, training of energy code reviewers, funding of code circuit riders, advanced code compliance software able to verify sophisticated integrated design strategies, etc.

- Considering the zero energy building design complexity challenges reflected earlier, regulatory processes that utilize more effectively the computational methods used in design would decrease time and resources and increase inspection quality. In these cases, the regulator is effectively a member of the Integrated Design team and relies on and trusts the computational assessment and may functionally be connected to the code compliance aspects via the computational toolset. In the future, regulators should be able to "plug and play" into the design team's process to check code compliance and move the building along its design and delivery stages quickly and efficiently.
- A widely accepted standard for integrated design process and methods for energy efficiency needs to be established by a nationally accepted authority in the building profession along with key endorsing entities.

5.2 Actions by the Consortium

- Gather existing demonstrations, case studies and other information, then package and promote them to the market.
- Work with others to collect cost data to enter into DOE's database of zero net energy buildings, or a comparable database.
- The Workforce Development working group should consider recommending grounding in building science, as well as BIM, in curriculum for design students and continuing education credits for design professionals.
- Convene a group to work on developing a broadly accepted definition and implementable or adoptable standard.
- Provide an annual report on progress in the market.

5.3 Actions by Others

5.3.1 AIA: Continue to implement its IPD Action Plan particularly to increase awareness and acceptance of this emergent change to practice, project delivery and the required business models to accommodate the change. AIA could also survey its members on costs related to zero net energy or very low energy buildings.

5.3.2 ASHRAE: Follow-through on its Strategic Plan goal and strategy to collaborate with other organizations and component suppliers to integrate passive and active elements of a building system, such as HVAC&R systems with fenestration, lighting, and thermal management to enhance the effectiveness of total building design and integrated practice. ASHRAE and its partners should move rapidly and aggressively to develop a set of net-zero AEDG documents, fully incorporating the latest knowledge on integrated design. ASHRAE and the Consortium can provide the promotion, education, training and other support required to ensure their widespread use.

ASHRAE Standard 90.1's Appendix G is the most widely used method for determining a building's energy. It is used by rating systems such as LEED for New Construction, and a nearly identical method is used in ASHRAE Standard 189.1. Appendix G uses the proposed building's shape and window to wall area ratio to derive the baseline shape and window to wall area ratio. Essentially Appendix G gives no energy savings credit for optimizing the window area for total energy use, so even though a slight reduction in glazed area may reduce the building's energy use, Appendix G does not recognize those energy savings. Similarly, if the team is considering two different building shapes, the one with the lower energy use is not necessarily the design that shows the most energy savings in Appendix G. Appendix G should be amended so that it encourages design teams to optimize both the glazed area and the building shape (not just the orientation) in relation to the total building energy use.

5.3.3 BIM related industry and professional organizations: The National BIM Standards Committee of the National Building Sciences Institute, its National Building Information Model standard (version 1.0) and the International Alliance for Interoperability have been addressing the issues for quite a while. Net zero energy may require special considerations such as integration of energy performance modeling.

5.4 Funding and Incentives

Funding and incentives are required in the short term to support early demonstrations and help get the market moving in the right direction. In the long term, codes will evolve and require much higher performance leading to the need for integrated design.

5.5 Federal Executive Order

An October 5, 2009 Executive Order requires federal agencies to implement high performance sustainable Federal building design, construction, operation and management, maintenance, and deconstruction. Beginning in 2020 and thereafter, all new Federal buildings that enter the planning process will be designed to achieve zero-net-energy by 2030. In addition, all new construction, major renovation, or repair and alteration of Federal buildings must comply with the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* (Guiding Principles). DOE and others should help all Federal agencies comply by providing education, training and technical assistance.

The Guiding Principles define a collaborative, integrated planning and design process that initiates and maintains an integrated project team in all stages of a project's planning and delivery; establishes performance goals for siting, energy, water, materials, and indoor environmental quality, along with comprehensive design goals; and ensures incorporation of these goals throughout the design and life cycle of the building; and, considers all stages of the buildings lifecycle, including deconstruction.

Appendix

Organizations (Needs some links)

- Advanced Building Systems Integration Consortium (ABSIC), Center for Building Performance and Diagnostics, School of Architecture, Carnegie Mellon University
- American Institute of Architects (AIA)
- American Society for Heating Refrigeration and Air conditioning Engineers (ASHRAE)
- Center for Integrated Facility Engineering (CIFE), Stanford University
- Institute for Market Transformation to Sustainability, Integrative Design, http://mts.sustainableproducts.com/Integrative_Design.html
- International Alliance for Interoperability - addressing BIM issues since 1994. It has branded its initiative as "buildingSMART".
- International Living Building Institute (ILBI), operated by Cascadia Region Green Building Council, http://ilbi.org
- National Institute of Building Sciences (NIBS) – WBDG and National BIM Standards Committee
- New Buildings Institute (NBI), www.newbuildings.org
- Northwest Energy Efficiency Alliance (NEEA) www.nwalliance.org - BetterBricks initiative (www.betterbricks.com) and the Integrated Design Lab Network it supports
- US General Services Administration (GSA) – guidelines, requirements and tools
- Sun Microsystems and Natural Logic - sponsoring OpenEco.org, an on-line community with free tools to help participants assess, track, and compare energy performance, share proven best practices to reduce greenhouse gas emissions, and encourage sustainable business innovation.
- US Department of Energy (DOE), Building Technology Program
- US Environmental Protection Agency's Energy Star program
- US Green Building Council (USGBC) – LEED criteria and guidelines
- World Business Council for Sustainable Development's Energy Efficiency in Buildings (EEB) initiative
- (add more key orgs???)

References and Resources

American Institute of Architects (AIA), *Integrated Project Delivery: A Guide (Version 1, 2007)* http://info.aia.org/aia/form_ipd_guide.cfm

ANSI MTS 1.0 WSIP Guide - 2007, Whole Systems Integrated Process Guide for Sustainable Buildings and Communities. http://www.delvingdeeper.org/pdfs/wsip.pdf

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Savings By Design, Participants handbook, (PG&E, SCE, SDG&E),
http://www.savingsbydesign.com/pdfs/2010-2012-SBD-Participant-Handbook.pdf

7Group and Bill Reed, *The Integrative Design Guide to Green Building*, Wiley, 2009

Sustainable, High Performance Projects and Project Delivery Methods - A State-of-Practice Report. September 1, 2009, Research sponsored by the Charles Pankow Foundation and the Design-Build Institute of America (DBIA).

Whole Building Design Guide (WBDG), National Institute of Building Science (NIBS)
http://www.wbdg.org/wbdg_approach.php and, Engage the Integrated Design Process,
http://www.wbdg.org/design/engage_process.php