CONSORTIUM for BUILDING ENERGY INNOVATION

REPORT

Title: Building 661 Integrated Design Process Report - Early Lessons Learned

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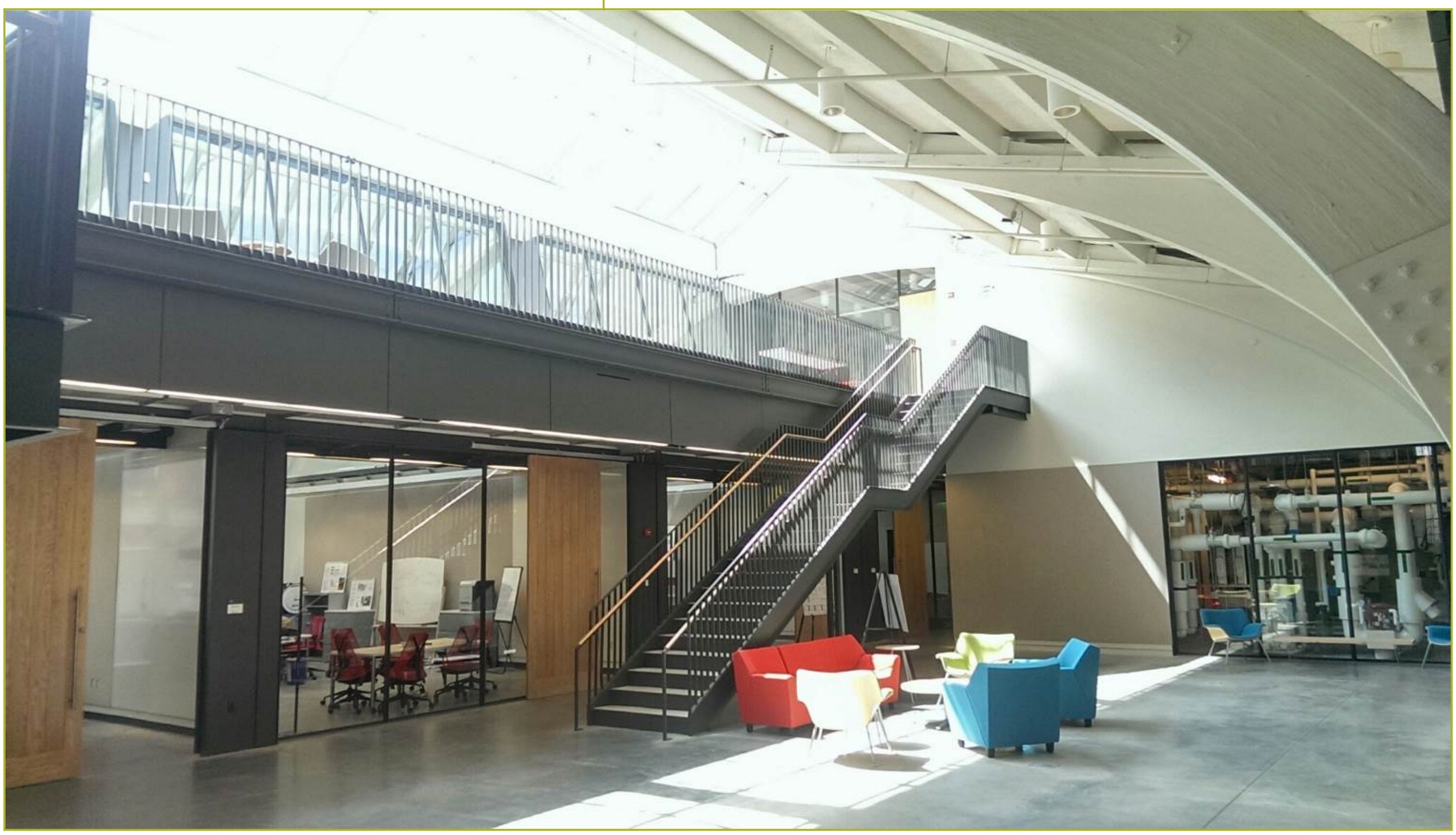

CBEI was referred to as the Energy Efficiency Buildings HUB at the time this report was developed.

REPORT

Report Abstract

CBEI performed a major retrofit of their headquarters. This report provides early lessons learned from the integrated design process.

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REPORT

Building 661 Integrated Design Process Report

Submitted by: Leslie Billhymer, University of Pennsylvania

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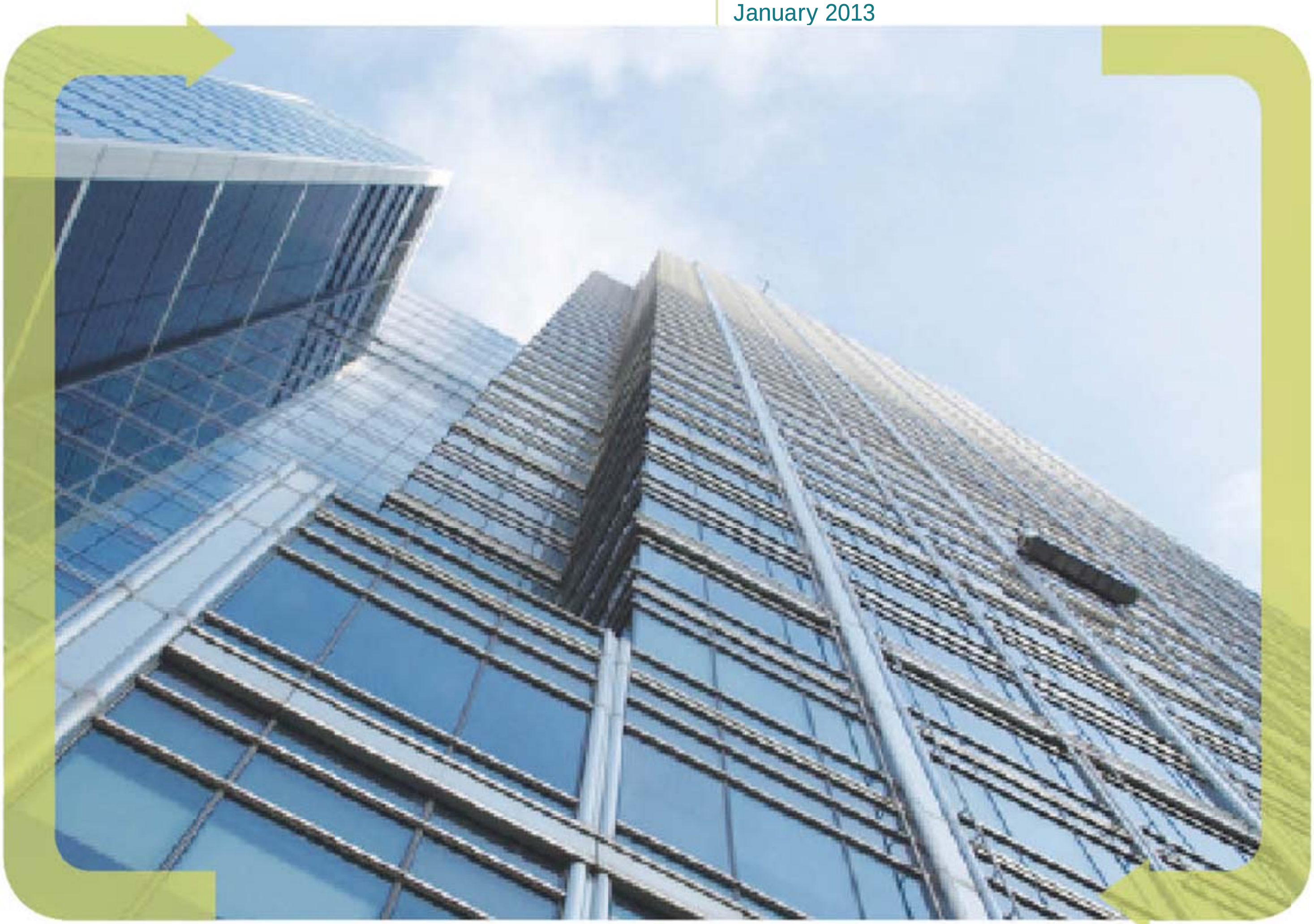

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KEYWORDS:

Energy Efficiency, Integrated Design, Integrated Project Delivery, Task 9, Technological Specifications, Energy Modeling, Retrofit, Research, Building 661, Deliverable 47, Building Systems

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Executive Summary

The Energy Efficient Buildings Hub was established in 2011 at the Philadelphia Navy Yard by Penn State University (PSU) with a regional energy innovation cluster grant from the Department of Energy. In addition to these funds to support the Hub's research program, the funds for to retrofit a future headquarters for the organization from the Commonwealth of Pennsylvania and the Department of Commerce. These two sources gave 33 million dollars together to support the retrofit project, and the Philadelphia Industrial Development Corporation (PIDC) offered building 661 as their candidate for the comprehensive building retrofit project that could be sold to PSU for a very small sum.

The Navy Yard is a federally run WW2 Naval Base that was deeded over to the City of Philadelphia and PIDC in 2000. The Navy Yard campus is attached to the city at the southern end of its' main bisecting thoroughfare, Broad Street. It contains an even, sprawling yard, dotted with new low-rise development and formal Navy buildings, a combination of mid-century modern low-slung red brick dormitories and taller former factories with steel-framed glazed facades. The Navy Yard site was chosen for its potential to provide both buildings and clients to test and implement integrated design and integrated systems retrofits in commercial buildings, and as the project is now approaching the completion of its second year of program work, the work is underway.

Faculty, staff, and employees of the EEB Hub's member institutions will use the Energy Efficient Buildings Hub headquarters as their living research lab for the duration of the project. The grant application committee consisted of 23 co-applicant institutions, who, upon acceptance of the award became the members of the organization. This group represents a mixture of public and private educational, economic development, and private companies, all of whom would contribute to the research agenda for the Hub. As of the winter of 2012-2013, that number has grown to 28 member organizations. Penn State will operate and maintain the finished facility. As the Hub was originally scheduled for 5 years of funding from the Department of Energy in total, the plan for the facility's use following the grant cycle will pass to the Department of Engineering at the school.

Retrofit demonstration projects are a key element of the Hub's work. They are test beds for integrated design and integrated building systems retrofit research. They range from gut-rehab comprehensive retrofits like the building 661 project, to subsystem specific replacement, to building operator and occupant behavior energy research and testing. Building 661 is located at 4960 S. 12th Street. This retrofit will be a featured achievement of the Hub, because the building aims to serve as a demonstration of an integrated project delivery approach to retrofit with an emphasis on scalable integrated systems. The Building 661 project aims to capture transferable lessons from the process that can be applied to other existing building renovations.

Part of the work of the Deployment Task has been the observation of the Building 661 retrofit process, a project which has recorded the tools and processes adopted by the Architecture, Engineering, and Construction Management services for the project. This project reports out on the observed and recorded aspects of the Integrated Design practices implemented in the building 661. This building project now sits within the larger set of retrofit demonstration projects, and aims to contribute to the Hub's goal of reducing energy consumption by 20% in 2020 in existing commercial buildings by providing a set of lessons learned at close range. While a few of the many hallmark methods of integrated design and Integrated Project Delivery had to be excluded from the building 661 building delivery process, many of these methods were implemented. Those are described in more general terms below:

- **Shift to earlier participation by those who will design and construct and manage the building:** Integrated Design and Integrated Project Delivery represent a fundamental shift from participation timeline in a traditional building delivery model to the participation timeline of an integrated design approach, where construction management, building suppliers, and building trades are involved near the beginning of the project through until completion.

- **Increasing risk sharing between building designers and building constructors:** Traditional building delivery processes confines risk to the parties according to traditional building process deliverables. The architects are responsible for problems in the built products that can be attached to the design documents, and building constructors are responsible for problems in built products that can be attached to the problems with the means and methods of the construction process. In Integrated Design there needs to be greater shared risk between these two professions, because both are involved from the beginning, making decisions that will impact the final product. Therefore, the contracts used for a building project need to increase shared risk between the designer and the constructor; they both will be "at risk" for the success of the final outcome.[1]

- **Compensating based on collaborative work:** In a traditional scenario, compensation is tied to profession-specific design or built deliverables. In an integrated scenario, compensation will be tied to work that is deliverable and process-based; in other words, the team will be compensated for addressing deliverables and the act of collaborating, as this is fundamental to delivering a superior built product.

- **Goals and metrics are defined collaboratively at the beginning of the process:** Successful collaboration begins with a team where every member has contributed to a shared understanding of what it will mean to succeed. This requires a robust value-creation phase where goals for the project are established along with a way to measure whether or not the project has achieved the goals.

- **Project planning centers around collaborative milestones:** Planning in an Integrated Design Process will reflect the nature of the work that is accomplished along the way. And since work is shared, so are the milestones that mark progress toward completion of the project. This is a fundamental shift from a traditional building delivery process, where professions each plan to complete a set of contracted deliverables. In Integrated Design project planning, the whole team contributes in the planning sessions to create a schedule for the best product the team can deliver with the project budget. The Milestones are collaboratively conceived and the work to arrive at each is collaborative and moves between professional groups along the way. [2]

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[1] (American Institute of Architects 2007)
[2] (Ballard and Koskela, Towards Lean Design Management 2007)

- **Building is designed to a detailed budget and reviewed collaboratively:** All building projects have budgets, so it's unrealistic to believe in one-size fits all design. Design and building technology solutions need to be tailored to the building AND to the project budget. An Integrated Design process entails a periodic review of the evolving design proposal with the project's principal actors: the owner, the designers, the constructor, and key consultants. At these reviews, a detailed budget is reviewed to spec the evolving design and project the design's construction costs. This in-depth budget review along the way will pay off during the construction period. In a traditional building delivery scenario, this review process does not exist. This often results in unexpected construction costs and change orders that can be anticipated and eliminated in an Integrated Design process.[3]

- **Integrated building systems have integrated performance specification:** Generating the delivery of predictable energy performance with suites of integrated building retrofit approaches and building technologies. In a traditional building delivery scenario, building equipment manufacturers and suppliers do not guarantee energy performance and have no mechanism for doing so; as a result, the process of predicting energy performance through to the implementing it built product is a risky endeavor.[4]

When one looks beyond the process and towards the building itself in its current condition and the preconstruction-phase building design, a rich set findings emerges. This report also elucidates the important features of the design and systems specifications of building 661. The documentation included here intends to draw a line between the robust recommendations offered to the project, the integrated design process, the physical givens of the building in its current condition, the energy modeling findings and recommendations, the programming for the building, and the as designed outcomes according to the range building subsystems: Enclosure, HVAC, Lighting, and Sensors and Controls.

[3] (Ballard and Koskela, Towards Lean Design Management 2007)
[4] (ICF International and National Association of Energy Service Companies 2007)

Building Description

Brief History and Context

4960 South 12th Street is commonly referred to throughout the Navy Yard and also within this document as "Building 661". Navy Yard buildings were given numbers that corresponded to the order in which they were built. Henry D. Dagit and Sons designed 661 in 1942 for the United States Navy at the same time several neighboring structures were being designed and built: a Seaplane Hanger (653), Temporary Barracks (655-658), Garage House and Pump Room (660), and Barracks for Crew of Ships (662). Its first function and purpose remained consistent during its use from 1942-1996. It is located at the Northwest corner of 12th Street and Kitty Hawk Avenue in the Philadelphia Navy Yard and is surrounded on three sides by adjacent structures to the west, south, and north.

Building 661 served as a Navy recreational sports facility that housed a pool, basketball courts, and a multipurpose room. Major renovations were performed in 1946, 1974, and 1986, though no considerable alterations to the use or massing occurred in these events. They included gymnasium floor replacements (1950), reinforcing of the wooden arches (1950), pool repairs (1973-1974), roof repairs and replacement (1975), and the removal of a second level bowling alley (1980). Additionally, several of the original window openings were filled in with brick masonry (1978).

Building 661 contributes to the scale and character of the Philadelphia Naval Shipyard Historic District with the help of several of those nearby that include building 489 and 104. Both 661 and 489 are two story brick masonry buildings with articulated roof profiles and large front setbacks which line the west edge of 12th Street. Building 489 to the north is planned to be renovated soon and has an existing connecting link that has been sealed off at the north elevation of Building 661. The collective continuity and materiality of buildings 661, 489, and 104, assist in creating a campus feeling in this area of the Navy Yard and serve as a unifying series of buildings for the open area and the proposed park. These three can be contrasted with the nearby warehouse block buildings that are each 8 stories in height, as they vary drastically in character, materiality and scale.

Building 661 Current Condition

Since 1999, 661 has been designated a historic structure and will follow the *Secretary of Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings*.[5] These standards give both general guidance about maintaining "historic character" and specific about how to address how to maintain specific building elements, materials, and treatments. The interventions in the 1970s and 1980s that occurred before the historic designation for the site compromised the original architectural character of the building. The retrofit will enable a restoration of many of these architectural features at the same time it enables the demonstration of energy efficient design strategies complementary to the original design.

Building 661 consists of a two story brick masonry head house 17 bays long and 5 bays wide with a stepped gabled roof and cupola as well as an adjoining larger 5 by wide high bay gymnasium and pool space. The two story head house has a concrete frame with a pile supported grade beams, CMU and drywall interior walls and glue laminated trusses supporting the gabled roof. The structural framing for the gymnasium and pool sections are wooden arches supported at grade on pile foundations. The structure has a brick façade on all four sides. The head house has an asphalt roof and the gymnasium and pool have a fully adhered EPDM roof. The building does not currently have an elevator or a sprinkler system.

Figure 1: 661 Front (east) View

Figure 2: 661 South View

Figure 3: Interior High Bay Space

Figure 4: 661 Rear(west) View

[5] (National Park Service)

The head house concrete frame and wooden arches are generally in good condition, though further investigation of required repairs to the arches will be on going. The roof is supported by precast concrete planks on wooden purlins. The purlin connections to the west wall have deteriorated from water infiltration and new connections are required. Several purlins have been replaced in the design. The concrete planks over the gymnasium have some rib reinforcement exposed and should be repaired. Additionally, a majority of the precast concrete planks over the pool area have exhibited some deterioration and need repairs.

In general, the exterior walls are in good condition. There is localized cracking that formed from the natural expansion and contraction of the brick and should be repaired. The exterior stair in the southeast corner shows some cracking and has been further investigated to its structural impact. Both the shingle roof and the EPDM roof will have to be replaced as both have open areas allowing water infiltration into the building. Temporary repairs should be made immediately to stop water infiltration into the building and continued deterioration. The wood gutters, cornices and fascia are all in need of repair and replacement and the cupola will require substantial restoration. Also, the precast capstones on the west wall must be removed and reset to stop water infiltration.

Figure 5: 661 Base of Exterior

Figure 6: 661 Water Damage

Figure 7: 661 Pool Area

Figure 8: 661 Exterior Stair

Integrated Design and IPD Approach

A building project's design and delivery process are driven by the many factors: the client's goals, financial context, the building's condition, the design team, and legal boundaries and constraints. For several years, ever-expanding portions of the building industry have been participating in the movement to promote integrated design and delivery practices in new and existing building construction practices. In some corners of the industry, such as new hospital construction in the healthcare building industry, disciplined Integrated Design and Integrated Project Delivery methods are standard practice. In these areas, stakeholders realize that they cannot afford to accomplish the project objectives without following these models. And yet, in other segments of the building industry, although Integrated Design processes are known to unlock more value, this model of practice is still not widely adopted for several well-documented reasons.[6] In these areas, traditional models, such as design-bid-build, persist as standard practice.

The work of the Energy Efficient Buildings Hub's work intervenes in the design process, the construction, and the operations and maintenance of building retrofits and requires a working process that unites the considerations for the entire life of the building early on in the retrofit process. This is why, in the Hub's first year Statement of Program Objectives, so much of the research related to the design process of building 661.[7] The Hub's researchers anticipated the need to make example out of the practices and lessons learned in the building design and delivery process to be able to both repeat them and develop them further in the implementation of other retrofit projects.

A host of resources exist on how to conduct an Integrated Design retrofit. These resources are manuals, how-tos, and guides that are sometimes interactive. Five well-known examples are presently available on the web and included here. Also, to note, these resources provide profession-specific perspectives on the transition from traditional practice to an integrated practice, so one guide does not fit all. For instance, AIA's IPD Guide is tailored to architects; the Lean Construction Institute's resources are tailored to the Construction Management Community.

1. The AIA's Integrated Project Delivery Guide
2. Rocky Mountain Institute's Retrofit Depot
3. The Lean Construction Institute
4. Better Bricks
5. Whole Building Design Guide

Building 661 benefitted from the AEC firms hired on the project all of whom have deep knowledge and experience in integrated design methods as well as the expertise from the EEB Hub research team. Balfour Beatty, for instance, has brought a great deal of knowledge and experience with Lean project delivery approaches that were implemented on the building 661 process.[8] The Penn State Office of Physical Plant included language that bound the core integrated AEC design service firms to implement an "Integrate Project Delivery"

[6] (Choi, 2009)
[7] (Department of Energy, 2010)
[8] (Lean Construction Institute, 2013)

approach. The AIA has developed a set of project guide and contract resources that can be utilized for IPD building projects. The next section discusses how the building 661 project could not fully implement the IPD model because of the Separations Act, but the stakeholders nevertheless implemented IPD methods in many aspects of the building 661 design process. The table below summarizes key aspects of the ways Integrated Project Delivery contrasts with Traditional Project Delivery methods.[9]

Just as the various guides emphasize different integration opportunities and methods, every project presents a different physical and social context in which to implement these methods. The design process is highly specific for any one project. In any attempt to isolate and describe certain project aspects must acknowledge that these integrated aspects enabled each other, just as team members carry the project forward together, so do the project's aspects support one another.

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 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

[9] (American Institute of Architects 2007)

Separations Act of PA and Integrated Project Delivery

The Separations Act of Pennsylvania passed in 1913 to promote fair competition and prevent bid-shopping for the various types of contracted work in building funded with public monies. The law buttressed efforts to protect worker rights, worker safety, fair wages, and training that suffered in contests to produce the lowest bid. Known as the multiple prime delivery system, it renders the public entity responsible for the management and coordination of four separate subprime contractors: the general, the mechanical, electrical, and the plumbing.[10]

This legislation passed during a time that demanded ways to protect workers, but the objections to this law explain that how pubic entities must assume avoidable cost burdens in managing the four contracts with the subcontractors. These burdens result in higher building project costs overall. Further, recommendations to change the law describe how labor and wage standards now provide protections that didn't exist in the Pennsylvania of 1913, when many states were passing similar laws.

The Separations Act complicates Integrated Design contract and fee structures. Integration requires early participation by the full set of design and construction professionals who will work on the project. The law blocks firms who bid to construct publicly funded projects from performing design-phase work. This is why arrangements for the expertise of construction consultants were brought on during the design phase in what were called "design assist" integrated mechanical and electrical consultants. Further, both the Economic Development Authority and the Department of General Services prohibit incentive pay by direct charge to the grants. As such service providers cannot be awarded money in the form of a bonus, profit-sharing or a commission. Federal and State laws prohibit funds from being awarded to incentivize final energy performance outcomes in the building, a practice that is becoming increasingly common in the building industry as a way to drive teams to achieve various goals connected to building construction, operations, and maintenance outcomes.[11]

[10] (Leavitt, McIlwee, & Gates, 2011)
[11] (National Renewable Energy Lab 2011)

Integrated Design Team Hiring

The building 661 project has worked to demonstrate an Integrated Project Delivery approach while following the requirements set forth by the Separations of Bidders Act of Pennsylvania. This process began with the selection of a design team. Due to the public nature of the project, members of the Penn State Office of Physical Plant and EEB Hub research team devoted effort to design team selection process to ensure that the service professionals hired for the work could create, maintain, and innovate according to Integrated Project Delivery protocols while abiding by the conditions of the Separations Act.[12] While several exemplary building projects have approached team selection by soliciting proposals from pre-assembled teams, the Penn State Office of Physical Plant elected to select them separately, requiring full-day interview processes to take place for short-listed project management, architecture design, and construction management services.[13] This enabled a detailed examination of the qualifications of the firms to be revealed along the way. See Figure 9 for final Organization Chart.

Project Manager Selection

All of the candidates on the short list for Project Manager were regional firms with Pennsylvania and New Jersey project experience, and none of them satisfied all of the desired criteria for the Project Management services. Even the best candidates lacked key experiences—the committee had to choose between candidates who had knowledge of but not experience with either Integrated Project Delivery methods or Building Information Modeling or both. The interview process served as a litmus test for regional expertise in these building project delivery methods and revealed experience gaps, even from seasoned regional industry leaders in project management. Whoever the committee chose would provide this the project manager key learning experience in integrated design and delivery project management methods.

Long-list Project Management firms: Hill International, McDanough Bolyard Peck (MBP), Elevate Architects, AEGIS, CB Development, Bertino, Watchdog, Blue Rock Construction
Short-list Project Management Firms: AEGIS, BlueRock, Hill International, Watchdog, and CB Development

Architect & Engineer

There were forty-four proposals for architectural and engineering services. The Architects specified the Engineer partner they'd chosen at the time they submitted an LOI in August of 2011. Several combined Architecture and Engineering firms applied. Because of the volume of responses, the selection of the architectural services went through two rounds with the joint PSU-EEB Hub committee. The first round narrowed the candidate list to ten firms, and the second round determined three firms that would be invited to an in-person interview in early September.

[12] (American Institute of Architects 2007)
[13] (Whole Building Design Guide 2013), (United States Department of Energy 2008), (New Buildings Institute 2012), (Better Bricks 2012)

In the first round, the firms were asked to provide a formal presentation of written materials that, among more general qualifications, provided both evidence of expertise in IPD (Integrated Project Delivery) and BIM (Building Information Modeling) as well as evidence of experience on building projects that could be related by the goals, building, and client. The selection committee asked for experience with the firm's experience with Integrated Project Delivery and Building Information Modeling. The selection committee reviewed these portfolios, and three firms were invited to give a presentation followed by an interview.

The interviews provided each team with an hour and a half for a presentation plus Q&A. The questions from the selection committee to the A&E teams as well as the closed-door deliberations focused on which team understood the broader goals of the EEB Hub and would able to take concrete steps in one project to tackle problems that the EEB Hub is working to solve at the scale of the market—does the firm demonstrate the ability to scale the lessons of integrated design processes to effect larger industry transformation? Did they show the appetite to work collaboratively with the researchers at the EEB Hub? Did they show expertise in designing spaces that both educate the users and that are functionally flexible as a living lab in building industry technology might require?

Long-listed Architecture & Engineering firms: BNIM/Revision Architecture, Ewing Cole, EYP Architecture & Engineering, P.C., FXFOWLE Architects, Kieran Timberlake, William McDonough + Partners, MS&R, Overland Partners Architects, Perkins + Will, and Stantec

Construction Management

Penn State received 20 proposals for Construction management Services. Eight firms were short listed and four firms were invited to make a presentation to the selection committee. The short-listed firms included a set of materials in their application packages that included a bid for pre-construction and construction scope and services.

The selection committee for Construction Management Services on the building 661 project was chaired by the Project Manager selected for the project a few weeks before, Steve DiBartolo from Hill International, and it assembled a selection committee from the EEB Hub and Penn State Office of Physical Plant. The most prominent issue that rose to importance for the project was their understanding of the work that would be required for the preconstruction phase, the phase when most of the integration and project planning would take place. The selection committee looked for demonstrated leadership on projects that Balfour Beatty won the proposal, as they had a clear understanding of how they would tie effort and a portion of their fee to preconstruction services for the project.

Long Listed Construction Management firms: Alvin Butz, Balfour Beatty, L.F. Driscoll, Gilbane, Skanska, Torcon, Turner, and Whiting-Turner

Design Assist Services: Commissioning, MEP Design Assist, and Integrated Electrical Design Assist

After the Architect, Project Manager, and Construction Management services were hired, the project hired three additional positions to support the core design team in the process of design, review, and specification. First, Chris Skowsky from Aramark was hired to provide design and construction phase building commissioning services. His role during the design phase of the project was to ensure that the systems specifications were going to achieve the energy modeled performance specification. The commissioning agent worked most closely with the project architect to review design documents and comment on those during pre-construction. And subsequently, during construction, the commissioning agent will conduct periodic inspection of installations of the mechanical and electrical systems as the building is coming together.

The project also hired a Mechanical, Electrical, and Plumbing Consultant and an Integrated Electrical Consultant to join the project as design assist consultants. The jurisdiction of the Separations Act of Pennsylvania requires that the project produce four competitively bid packages for the construction phase of the project, and thus any consultant to work on the design phase of the project would not be eligible to bid on the construction, a fact that the design team anticipated would make hiring these assist consultants a challenge.

Element Mechanical Services and MC Dean were hired as MEP Consultant and Integrated Electrical Consultant respectively. Element's main role was to make sure that budgets for construction services were accurate for this local market; this comprised approximately 50 % of the effort. Element also commented on the constructability of the design by reviewing drawings along the way. MC Dean's role was similar to Elements in that he reviewed the design to assess constructability, function, and pricing.

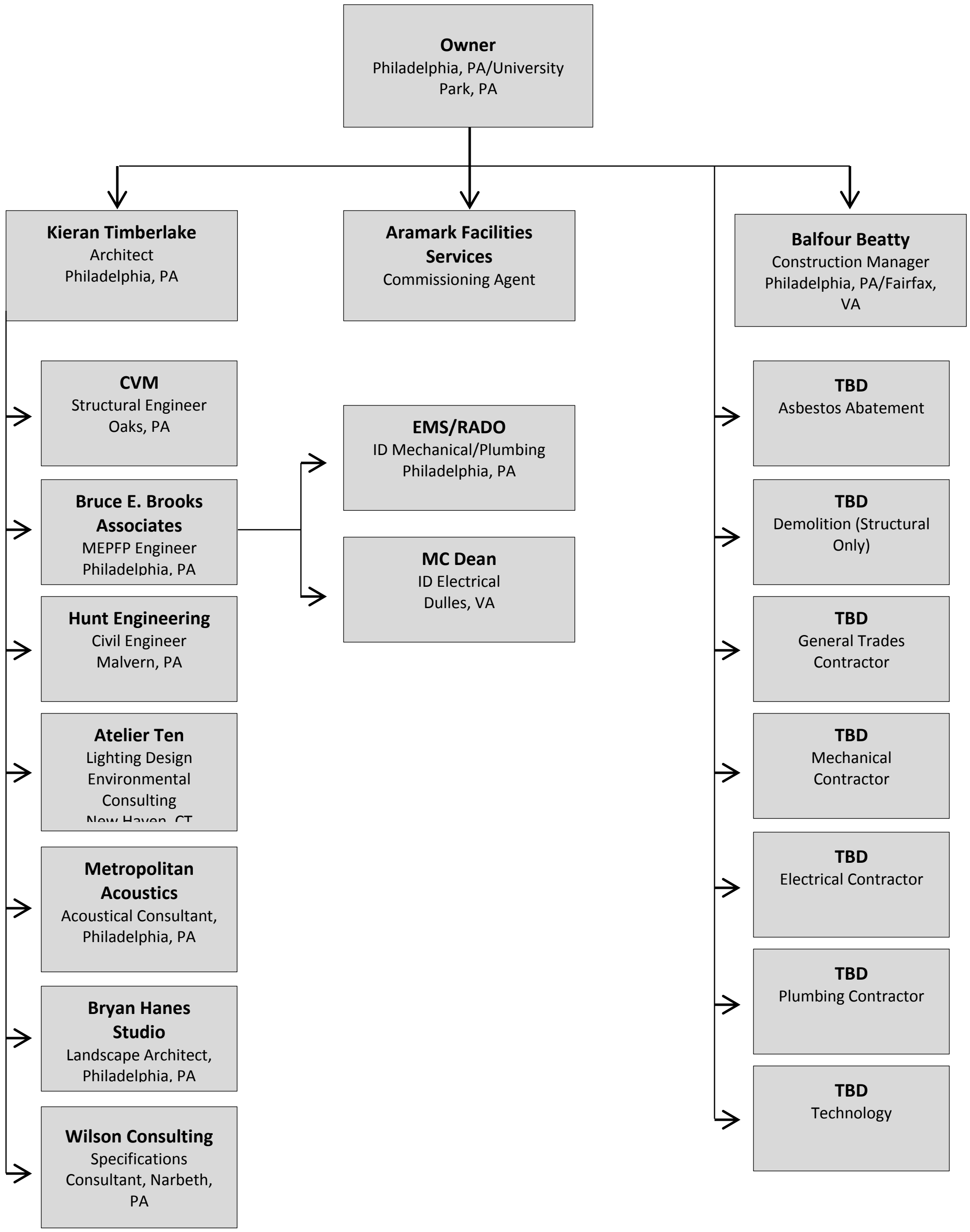

Figure 9: Project Organization Chart of Hired Design Services (Penn State)

Project Collaboration Addendum

In Integrated Design there needs to be greater shared risk between those who design and those who build, because both are involved from the beginning, making decisions that will impact the final product. Contract structures determine how risk is attached to the multitude of design and construction tasks that occur throughout a building design and construction process. In a design-build project, there is a great deal of shared risk for the design and construction tasks, and in a design-bid-build project, there are traditionally established boundaries of risk that are divided between those who design and those who build the project, as these parties are contracted separately with the owner.

The Separations Act determines that this project must follow a design-bid-build contract structure. Because of this, the project used a Collaboration Addendum (CA) to define collaborative principles and practices between the parties who would design and those who would construct the project. Though the CA does not carry any financial risk, it has been used as a tool to agree upon practices that have been implemented in the pre-construction phase and will be in the construction phase of the project. Penn State OPP contributed the CA for this project.[14]

The team embodied the spirit of the challenge to cultivate meaningful collaborative practices by exhibiting the willingness to establish project habits and protocol wholly independent of the contract terms with financial risk attached. The architect, project manager, construction manager and the consultants established practice standards for the project budget and schedule planning (more detail follows in the Planning and Budgeting sections of this report). These practices helped the team to regularly reach consensus design decisions and confident estimates for the construction of the project that helped the project achieve progress according to a tight schedule. During building construction, the collaborative focus will lay in the coordination of the construction work among the multiple primes. Balfour Beatty will host weekly planning on site which intent to increase construction outcome reliability and decrease construction time.

[14] Appendix A: Collaboration Addendum, V6.0.

Defining Project Goals and Values

Values Setting Phase One

IPD guidance encourages early goal definition, because the best way to start successful collaboration on a building project is to make sure that everyone has a shared understanding of the goals and desires for the renovated building. IPD approaches advise a building project to take on a value-creation, where goals for the project are established along with a way to measure whether or not the project has achieved the goals. This is one of the essential steps in the IPD's "team formation" phase.[15]

Setting goals for the building 661 project provided opportunities for the Hub leadership and the EEB Hub design team to articulate how the building project relates to the goals of the organization. The first opportunity to do this was to define the expectations for the built result amongst stakeholders in the newly formed Greater Philadelphia Innovation Cluster (the EEB Hub's first name) in the winter of 2011.[16] The building 661 retrofit process commenced as the project itself began, and the building project and the deliverables of the organization were linked. Not only were researchers across the Hub contracted to support the design process in a variety of ways- through modeling support, technical specifications, and by recording the process to inform other regional retrofit projects, but the building 661 design processes provided some of the first occasions for the EEB Hub investigators to gather.[17]

To help clarify the goals and intentions for the retrofit project, Penn State Office of Physical Plant hired a Philadelphia firm that specializes in facilitating integrated design projects, Re-Vision Architecture. They planned a day-long workshop held at Carnegie Mellon's Robert L. Preger Intelligent Workplace Lab. This was the first step in the process to gather EEB Hub investigator input to from the project's goals and the space requirements. The agenda took the 8-person group of engineers, architects, and building technology experts from several of the EEB Hub member organizations through a sequence of listening and brainstorming exercises to gain clarification on a set of topics related to the process of making decisions for the programming. The facilitation between the dozen participants occurred through recording answers to open-ended questions on butcher block and then voting on the priority items, which are included below.

1. Ooze innovation. The work of the HUB should be visibly apparent.
2. House and foster collaboration between research, training, and commercialization activities focused on clean and energy efficient processes, policies, and technologies.
3. Function as a Living Laboratory to research and demonstrate over time the processes and products identified and/or developed by the HUB as scalable retrofit approaches for energy reduction that are market ready or near-market ready.
4. Serve as a regional resource that makes energy efficiency sexy to building owners, researchers, policy-makers
5. Demonstrate the intersection between energy efficiency and energy effectiveness (e.g. efficient spaces that are also comfortable, healthy, functional, appealing)

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[15] (American Institute of Architects 2007)
[16] (Department of Energy 2010)
[17] (Department of Energy 2010)

These goals were established to support the process of specifying space needs (in SF) and uses (in program terms) for the final building, a process that unfolded over the two months following this initial convening at Carnegie Mellon. After this first event, members of this committee facilitated communication with the broader EEB Hub network, and then collected that input to provide it to Re:Vision who combined all of the space requirements and refereed discussions about ways to reduce space requests when the areas asked for outsized the area of the building. As investigators from the different member institutions were asked to indicate how they might use the final built result, they were asked to describe spaces that meet these goals in addition to serving their own purposes. Revision crafted the programming plan that was included in the RFP for proposals for architectural design services several months later.

Project Values Setting: Phase 2

In late 2011, Penn State Office of Physical Plant hired the core design team for the project, the Hill International, Kieran Timberlake, and Balfour Beatty. The task of establishing a set of project values became the first opportunity for the core team to meet with the Energy Efficient Buildings Hub Operating Committee, the leadership committee of the Hub. Integrated Design, Integrated Project Delivery, and Lean Project Delivery authorities agree that one important first step in project development is this goal and/or values creation step among the primary stakeholders on the project, which include the design and engineering services.[18] Balfour Beatty enlisted consulting services from the ReAlignment Group, an outfit associated with Lean Construction Institute building industry research, to facilitate.

These values would be crafted into brief statements that would be referenced during the design process to arbitrate design and engineering decisions along the way. The process to arrive at these statements would be similar the one followed earlier in the year, but different in that the result would be a statement of values as opposed to goals for the project. In the words of the values session facilitator, a project value is something that is "intrinsically desirable", "irreducible" that "supports the greater mission for the organization of the building project" whereas a project goal is something that represents a project target or objective. Project values may also be weighted against each other in importance whereas goals are in themselves absolute. Integrated Design guidance suggests that establishing project goals and/or values is important because it allows project participants to establish an understanding of project outcomes that will be held in the center of a framework which supports all participant objectives and values.

The session consisted of a half day with a group of 20 people from the EEB Hub Operating Committee and the 661 design team. The first step in the session focused on a discussion of the state of the building industry; participants were asked to formulate three statements that captured ways to change the building delivery process and one thing about the building industry that should be preserved. The output from one group included, for example three items to change: 1) opportunistic retrofit process, 2) integrated technology design, and 3) design for operation and maintenance; and this group's item to keep was the passion for people in the industry. These ideas were shared grouped into eight categories. These materials served as the basis for crafting the project's statements of value, listed below.

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[18] (American Institute of Architects 2007), (Lean Construction Institute 2013), (Whole Building Design Guide 2013)

Figure 10: Group Input Values Setting Phase 2

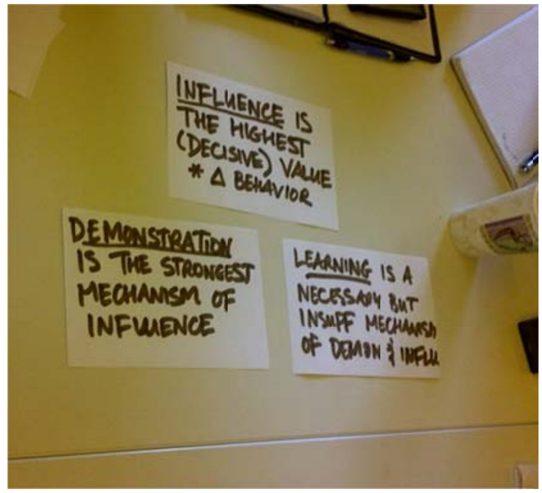


Figure 11: Values Setting Phase 2

Figure 12: ReAlignment Group Consultant

Figure 13: Group input Values Setting Phase 2

1) Influence: As a regional collaboration creating national energy efficient innovations that foster job growth, economic development we will influence the industry to design, implement, and operate integrated energy efficient renovations. We will influence public owners to use integrative project delivery processes.
2) Repeatable Demonstration: We will demonstrate incorporation of repeatable energy efficient technology, processes and procedures that are affordable, workable and efficient. We will demonstrate that public projects can deliver projects on an integrated basis within the procurement challenges this project faces.
3) Learning: We will use processes and technologies that allow us to learn and share our learning about the efficacy, affordability, repeatability and constructability of efficient and effective energy retrofits through synergistic integration of dependable components and subsystems.
4) Collaborative Environments: We will create a collaborative, multi-dimensional and highly functional work environment to serve both short and long term goals and provide a nexus for regional demonstration, learning and influence in accordance with GPIC requirements and Penn State educational goals.
5) Systems Integration: We will create efficient and effective energy retrofits through synergistic integration of dependable components and subsystems.

6) Cost Certainty: We will be good financial stewards and will spend all available initial funds to maximize scope, minimize long term facility costs and with constant consideration of premium/affordability.
7) Time Reliability: We will be a highly reliable team who makes decisions at the most responsible moment and creates a safe and quality work environment.

The core team responds:

The core design team favored this values setting process in general. Team members testified that the real value is not defining better values, necessarily, but in that the process forces everyone to take ownership of the results. Because the mix of stakeholders were present, the participants all own them equally.

Design team members also found some drawbacks to the values definition process on the project. Because the values grew out of the Hub goals defined during the programming process, they myopically focused on the mission of the Hub. The designers testified they should have been more vocal about certain aspects that were valuable to them in their design practice. Also, the design team believed key representation on the client side missed the event. The PSU OPP who craft and implement the school's design guidelines didn't attend this session, and their priorities weren't represented there even though they had a heavy bearing on design and budgeting decisions throughout the design process.

All members interviewed from the integrated design team emphasized that the values need to be comprehensive and include all the proper stakeholders. Setting goals within individual service firms and tracking progress towards those goals is often standard practice within architecture and engineering firms, but this does not replace a step where all key stakeholders are present to define those goals collectively for a project. These participants should include but not be limited to building owners, future building occupants, the core members of the design team (Architect, Engineer, and Construction management), building retrofit suppliers, and present and future building operators.

Project Governance

Building 661 has a more complicated client, user, and building program than is anticipated to be the case in other regional retrofit projects. The client and user are multifaceted for the near to midterm and also expected to transition permanently at a to be determined time in the mid to long-term future. In the situation of the near to midterm, the building users include Penn State University faculty and staff who work on the Energy Efficient Buildings Hub project but is not limited to that group. The Hub project involves sporadic use by researchers from 28 different organizations with a core set of full-time users from some of these groups. PSU and the design services understood that this was an important complexity to address. They needed a way to organize the means of decision making with and garnering input from this complicated set of stakeholders. In order to conceive this structure, Balfour Beatty again enlisted the ReAlignment Group to guide the Hub through the process of designating these groups and assigning the responsibilities of participation. Dick Bayer organized a one-day session between the Penn State Office of Physical Plant (employees of the University) and the EEB Hub Operating Committee (the administrative decision-making body which includes members from several member organizations of the EEB Hub).

The facilitator's stated the goal was to help this group decide what the decision making groups would be, to populate those decision making groups with members, and communicate the commitment the member roles would require. Dick Bayer introduced the R.A.C.I.O system to guide participants to designate and agree on the roles of the individuals as they were being mapped into four groups, the Integrated Design Team, the Integrated Project Team, the Building Steering Committee, and the PSU Executive Steering Committee. These groups all included a mix of stakeholders from PSU and from the other organizations. It would be the role of the Integrated Project Team to convene these groups for different purposes to facilitate that the project stay on track to completion. The Penn State University Groups that granted approval at stages along the way such as the PSU Design Review Board and the Board of Trustees are not included in this discussion as their membership resided within the PSU organization unlike these committees that were formed especially for this project.

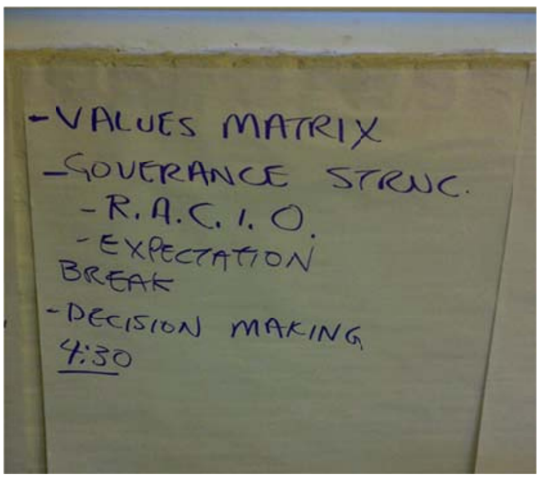


Figure 14: Agenda Governance Workshop

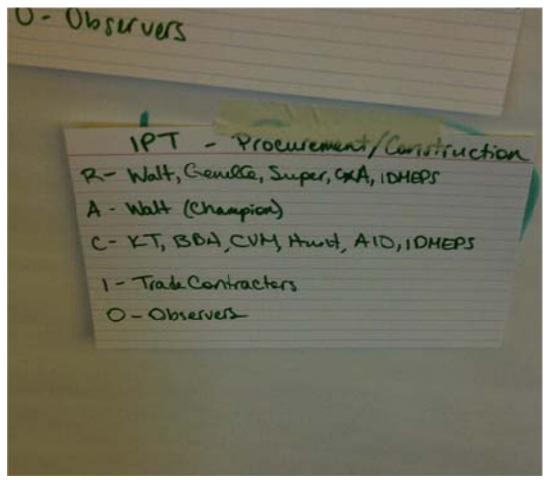
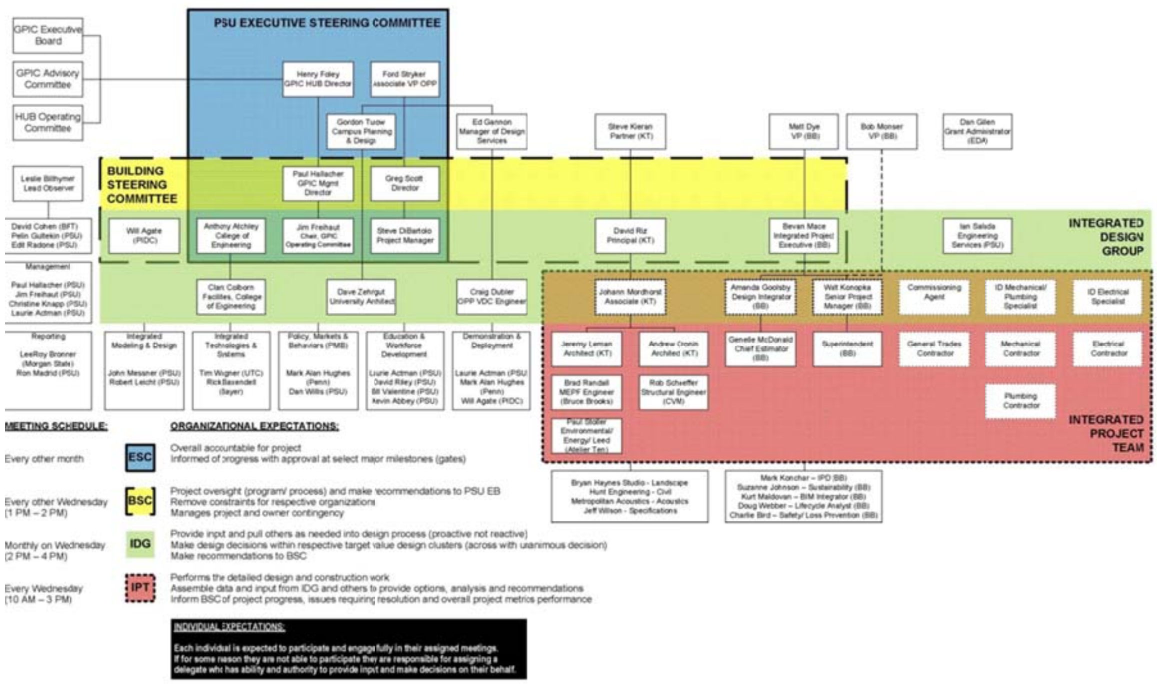


Figure 15: Breakout Results Governance Workshop

The Building Steering Committee was formed so the design team could conduct design and budget reviews every two weeks as the project progressed. The members included PSU office of Physical Plant, the PSU Department of Engineering, EEB Hub Deputy Directors, the Architect, Project Manager, and Construction Manager. They made the lion's share of the decisions by processing authorization for any changes to the consultants, approved some of the deep surveying, the design, dealt with some user requirements, and made final design finishes decisions, for example. This group met every two weeks throughout the design process.

The Integrated Design Group was established to interact throughout the process with the EEB Hub as a client and future user. EEB Hub Operating Committee members and researchers interested in design outcomes were included in this group. These meetings allowed the design team to attain the program requirements of these future users in a controlled format, to avoid ad-hoc requests from the broad network of EEB Hub investigators. This convening group provided a forum for the member institutions to provide input and reactions according to their space needs, program needs, technology needs, and preferences. For instance, it was through this group that the equipment to be installed in the building's research labs was selected. This group met once a month on a regular schedule.

The Integrated Project Team performed and will continue to perform all of the actual design and construction work and communicates with the other bodies throughout the pre-construction phase. The Governance chart in Figure 10 shows the membership of the three bodies overlapped each other, facilitating communication between the bodies that flowed through individuals. Much of this report will cover how they implemented integration in their design process and the designed result.



Deep Due Diligence- evaluations of the building's existing physical condition

Because building 661 has been vacant for almost 20 years a series of due diligence evaluations were commissioned during the first half of the design phase. While many of these related to code requirements, such as the geotechnical survey, the geothermal survey, the existing structural survey, and the hazardous materials survey, consultants performed two additional surveys, the blower door test and the thermal imaging test, to ascertain detailed information about the performance of the building envelope and its heat transfer characteristics.

A calibrated blower door test measured the building's air tightness. To perform one of these tests, a fan is situated in the doorway of a building and turned on to suck air out of a building, thus reducing the air pressure. Sensors then detect the air infiltration in the places of gaps and leaks.[19] A thermographic inspection makes thermal defects visible by capturing surface temperatures, air leaks, electrical system defects, excessive friction in mechanical systems, and/or inadequate insulation will show up in these images. This test did not take place in time for its results to be factored into the design process.

The core team responds

The blower door test was completed in time to impact the building design process; the results of the test were inputs in A10's October energy model. This helped to calibrate the energy model more accurately to the existing condition; the value of the air infiltration rate from the test measured higher than the default value that would have been used in its' absence at 0.60 CFM75/ft^2. Feedback from the team recommends that these tests be administered locally on batches of buildings, separated by building type and age, to establish more accurate default values that have been measured and tested against actual buildings.

[19] (United States Department of Energy 2012)

Integrated Design Team Planning

The building 661 project made its commitment to an integrated project delivery approach at the outset by asking all of the service firms hired on the project to budget extra hours during the design process for project integration than they would on a more typical design-bid-build project. These hours were distributed throughout the design process between working sessions with the Integrated Project Team, planning meetings, and budgeting meetings. Balfour Beatty's design integrator managed the project's master schedule that runs from the beginning of the design process all the way through the completion of construction. This schedule coordinated with and included Kieran Timberlake's design schedule that laid out a plan to produce detailed design specifications as well as Penn State's required design review milestones. Balfour Beatty integrated these various schedules in Adept management model and software.[20]

While it is true that extra hours were estimated by the Architect and Construction Management firms during the design process to anticipate the time to be spent on integrated activities on the project, Balfour Beatty describes how in an idealized situation, this planning process is not a significant addition of hours. The goal of Adept is ordering what may seem illogical information and efficiencies. Following the method means you've got the right people in those decisions. An example is about durations of certain work examples with the design team, and a large number is given for the time duration of different tasks. Out of those 25 days specified to finish a task, it only takes 3 days to do the work. So theoretically, if the planning is set up right, it should be more of those hours happen early as opposed to having more hours. It follows that if some part of the team uses their traditional planning means, then you're not getting the efficiency with the project overall that you should. The process and software are designed so that the total work hours are not greater than on a traditional design-bid-build project, but they are distributed differently. And if the process does require more hours, it's because the team is learning to adapt to a new way of planning and working.

Adept is designed to be a project management software for the design process of building projects; it is distinguished by its' ability to incorporate iteration into the design process and look at how multiple things need to be done at the same time. In these weekly meetings, construction management, project management, architectural design and any other necessary consultants would participate in a conference call or video conference to coordinate work schedules and transfer necessary information between parties according to 'just-in-time' project management techniques researched and promoted by the Lean Construction Institute.[21] In their project management research, LCI distinguishes between the practices of scheduling and planning, where scheduling involves 'pushing' work to completion according to a structured framework and planning involves 'pulling' work to completion according to 'just-in-time' principles, where work is completed not to early nor too late and in coordination with other stakeholder work on a project.[22] According to the project team members on the building 661 design process, this software enables both pull and push planning methods.

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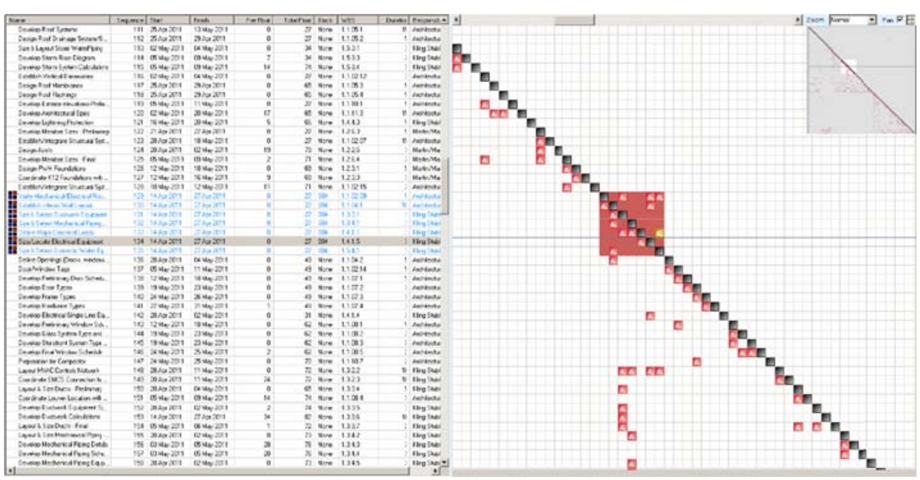
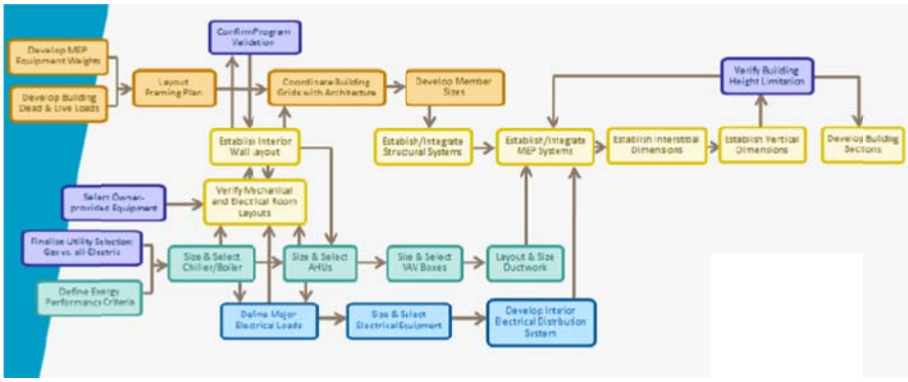
[20] (Adept Management Limited 2013)
[21] (Ballard 1995)
[22] (Ballard 1995)

Balfour Beatty implemented the planning model and managed the planning week to week with the core design team and any necessary consultants. This type of planning regimen is familiar to those in construction management but not as familiar to those in architecture. The architect and the construction manager held two separate contracts with Penn State on the building 661 project; because of this, it is more difficult to institute a process whereby architects and their consultants respond to a work plan designed by the construction manager. On design-build projects, the contract aligns the scope of work with the processes put in place by the design-build entity. In the case of the building 661 project, the parties all agreed to participate in certain collaborative working processes, and integrated design team planning was one of these.

Balfour Beatty Construction's design integrator implemented the Adept planning model by managing the software model and hosting weekly planning calls. Ahead of the call, the participants would complete an excel work plan that consisted of a set of tasks, a percent complete and comment-based reporting format. The call agenda typically covered the work plan for the upcoming week and ensured that everyone has the information necessary to complete his/her portion. Over the course of the call, the design integrator established how to adjust the master work schedule according to the discussions. At the close of the call, design team members would be sent a new work plan for the following week that reflected the progress on the full set of concurrent work for the project. The activities in the work plan related to deliverables 1-2 weeks out. The design integrator notes that a high level of maintenance is critical to this process, because if the logic did not flow, then people stop trusting it, and stop being accountable. Below is a sample screenshot of a master schedule in Figure 11, with a design loop highlighted in red. The logic flow related to that design loop follows in Figure 12.





The core design team responds

The design team offered mixed feedback about the integrated design planning process. A great deal of value was derived overall from speaking weekly about planning, progress, and information exchanges. BBC believed it helped the architect possess a depth and breadth of information that could be called up and conveyed to owners during the design process. The designers believed the process valuable overall and interested, perhaps on future projects, how to define those tasks in a way that they hold true for the course of the project. The schedule needs to be detailed enough to understanding the key information exchanges but be general enough in that they can come in the different design trajectories. There needs to be some way of doing that that captures those key information exchanges, but is flexible enough in that it doesn't require so much effort.

BBC revised the planning process over the course of the project, to build more value into this weekly excersize. At first, they asked design team participants to fill out and submit work plan spreadsheets. To increase the value of the process to participants, they changed this step to require a less time formal preparation requirements in the form of a description of top activities that are being worked on and corresponding needs to complete those items. This change was designed to tailor the process to the way people are most effectively going to consume the information on the calls. BBC added that a dashboard element of the program was not incorporated into the project likely would have been valuable. Kieran Timberlake testified that the work plans required in the first part of the design process created an undue administrative burden for a project of this size and scale. They offered that the process was extraordinarily time consuming at the level of detail that was captured in Adept.

Integrated Design Team Budgeting Process and Estimating

The building 661 process used Target Value Design principles to structure the building 661 pre-construction phase budgeting process.[23] Authors and innovators of TVD practices describe it as "lowering the river to see the rocks," a metaphor for self-imposing necessity as a means of innovation and continuous improvement. The project manager of the building 661 project described how the budgeting practices allowed the integrated project team to push as much money into the building as possible.

One of the main values for the building 661 and 7R project are to spend all of the resources granted to the project and not a dollar more, captured in the "Cost Certainty" value. To ensure this, every two weeks, the project manager and the construction management estimator facilitated a budgeting call with the design team. This allowed the project to keep a very tight budgeting cycle that ran alongside the design changes in the project. The designers maintained an up-to-date Building Information Model (BIM) and every two weeks passed that along to the budget estimator at Balfour Beatty. The budget estimating team would then take off quantities for materials estimates, and revise the construction schedule for a construction labor estimate according to the new model to provide a comprehensive new estimate. When an estimator and an architect are sitting together going through a detailed review of the building design, a reliable estimate can result.

There are a couple of features to highlight in this process that followed the Target Value Design approach. The main feature was to separate the two building projects supported with this block of funds into two buckets that reflected PSU's priorities to first build the EEB Hub's future headquarters and be able to achieve the high demonstration values for that retrofit. As 661 was the project's top priority, it had access to funds first. Funds still available would be devoted to the 7R project. By creating these fund groups, the project could more easily adhere to the project values. Also, throughout the design process, the team would work together to design to 95% of the construction budget. To prepare for the case that the budget came in with less than the money spent, the team prepared a list of alternate design features that could be added onto the construction scope during the construction process. This prioritized "wish list" will be prepared going into construction for a set of items that can be at the ready to be deployed and built into the project if the resources support this.

The budgeting process from beginning to the end of the pre-construction design work traced a path of budget uncertainty (and higher contingency) to budget certainty (and lower contingency). At the beginning of design, the Penn State OPP held design contingency at 10% and construction contingency at 2.5 million, 10% of the construction budget. Before construction starts, design and construction contingency are both held at 5% of the total budget and the estimating contingency is at 0, as the bid is the estimate. As the charges for "bricks and sticks" go up, the project savings in the construction portion increases as efficiencies are discovered and worked in to the plan. As the contingency dropped, the integrated design team built up a list of alternates that would be purchased as funding becomes available during the construction process by freed up contingency or other project savings. The final design amounts to 95% of the construction budget and and have alternates listed at 105% of the construction budget. The desired case is to enter into

[23] (G. Ballard 2006)

construction with a 2.5 million contingency and have resources to pay for the all of the alternates.

The core design team responds

Feedback on the budgeting process on the project is unanimously positive. The team saw the value in getting feedback every two weeks on design changes. The architect commented that the cost model was updated twice as often on the 661 project than on a typical project in their office, and this resulted in smaller overruns and underruns, so that the design deviated less from the budget targets. Construction management also sees the benefit in not having to rely on the designer's estimator in the case of a construction project they will eventually inherit. Construction managers often find they have more accurate cost modeling techniques because of an awareness of a building market in which they are more deeply situated than an architect often is.

The certainty of the cost model grew from the collaboration sessions where Balfour Beatty's estimator would go through the estimating work according to an analysis of the BIM model. By being in the same room, the designers and the estimators could communicate necessary information to understand how each other were thinking about the cost and design that did not either exist in the drawings or on the spreadsheet. This helped to uncover details that were not yet in the drawings but could be communicated verbally. The team agreed how this process, in particular, proved productive because of these biweekly, tightly coordinated sessions.

The team also testified that this process not only led to cost certainty but increased the design value. Bruce Brooks testified that, on a normal project, an engineer wouldn't know until the end when they need to pull something out and make it cheaper. The more notice one has for that, the better coordination and design value you have to redesign for that alteration.

BIM Execution Plan

Building Information Management Project Execution Planning (BIM Plan) is becoming an increasingly common practice in Integrated Design building projects. This planning outlines the overall vision along with implementation details for the design and construction team to follow throughout the project by defining the uses of the BIM models within the process. The goal for a BIM Plan is to stimulate and direct additional communication and coordination by the team members during all phases of a building project. This plan defines the scope of BIM implementation on the EEB Hub project by: identifying the process flow for BIM tasks, defining the information exchanges between parties, and describing the required project and company infrastructure needed to support the implementation. [24]

Penn State OPP initiated the BIM Plan for buildings 661 and 7R with Balfour Beatty, and Kieran Timberlake collaborating in January, within 2 weeks of the Values setting and Governance setting workshops. Each organization specified a BIM Model manager. The BIM Plan that PSU OPP brought to the project is a preconceived matrix of possibilities that the

[24] Appendix B: BIM Contract Addendum and BIM Project Execution Plan, Pennsylvania State University.

project customized for the retrofit of Building 661 and the new construction of Building 7R. This matrix of possibilities is categorized by BIM uses during different project phases. For instance, the first matrix is “BIM uses during planning”, the next is “BIM uses during design”, etc. Next to each of the possible BIM uses, Penn State OPP has indicated whether or not this BIM use is Required, targeted, maybe, or not pursued at this time. Within the first phase's table “BIM uses during planning” an example of a required BIM use is Programming: Analyze spatial program and requirements and accurately assess design performance in regard to space standards and regulations”. An example of a maybe BIM use is “4D Modeling: Plan project construction sequence”.

The BIM Plan fosters integration on the project by facilitating an agreement by the project architect, construction manager, and the facility manager of the future building to agree on the roles and uses of the BIM model. It allows each to understand the other's uses for the model that will eventually define the as-built condition of the building. It also builds in steps where the team collectively reviews the model along the way to monitor the development of the project through the modeled object or to perform “clash detection” for the building design. This step allows the team to anticipate any spatial conflicts in the plans for the building's mechanical, electrical, or plumbing systems. A clash detection step was included in the pre-construction process of building 661.

At a high-level, the intended sequence of BIM Model information exchanges follows: at the end of pre-construction, the architect produces a “Design Intent Model” and gives it to the contractors to create a “Means & Methods Model”. The Contractor then will build into the model any changes that occurred during construction and finalize the “Record Model” at the end of Construction to the owner. [25]

Energy Efficiency Technology Specification and Performance Goals

EEB Hub Research on the Technology Specifications for Building 661

The first charrette for the systems to insert into building 661 occurred before any of the design team had been selected. Its organizers wanted to marshal the knowledge of the EEB Hub expert network to provide a set of technical specifications for the building systems to include in the building 661 project. It convened approximately 70 building industry actors invited to participate from the 23 EEB Hub member organizations at the time, a mixture of academic institutions and private regional companies in the building industry. It was an event that unfolded over the course of a day and a half.[26]

The Hub intended several goals for this workshop. First, develop whole-building and system component goals for building 661, and second, identify key technologies for consideration in building 661. The workshop organizers asked participants to think about the performance goals for this retrofit and others in the region, the priorities of the space, and how building systems could be showcased in the building. The first day consisted of carefully planned brainstorming sessions and each focused on a different intended subsystem of the building. This format enabled the breakout groups to focus on bundled

[25] Appendix B: BIM Contract Addendum and BIM Project Execution Plan, Pennsylvania State University.

[26] (Loftness, Aziz, Lam, & Lee, 2011)

solution sets that could be applied to the building 661 retrofit and otherwise. To see the full results of this event and the research effort that flowed out from the event, please see the full Greater Philadelphia Innovation Cluster Expert Workshop Report.

These groups were organized according to four building systems: Enclosures; HVAC and Energy Generation; Lighting; and Networking Sensors, and Controls. A facilitator in each of the breakouts provided a loosely structured process for decision making that relied on a set of pre-prepared technology cards cataloguing the myriad technologies market available according to the four systems types; these technology cards were index cards that included key technology specification information, such as energy consumption information of performance specification. The participants then sorted the technologies according to their viability according to one or more of three categories: as operational technology or system; as a research/test-bed technology or system; or as an educational/demonstration/showcase technology or system through the use of colored stickers that could be applied directly to the technology cards. The cards were designed to be sorted and edited, enabling maximum participation and knowledge sharing by the participants.

Figure 19: HVAC All Source Technologies

Figure 20: HVAC 661 Operational Mandate

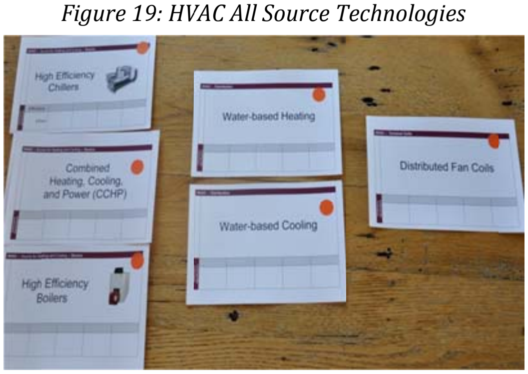


Figure 21: HVAC: Water Scenario

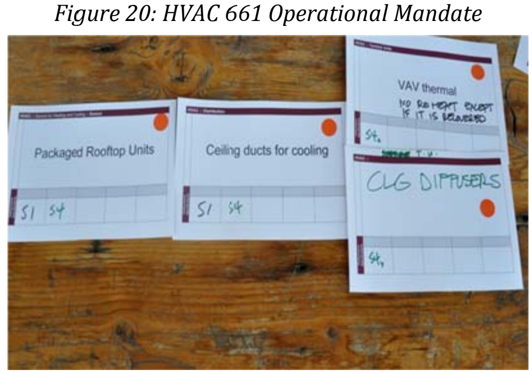


Figure 22: HVAC: Air Scenario

Enclosure Breakthrough Recommendations:

1. Daylighting, for both task and ambient needs, as long as possible (also recommended by the lighting breakout session).

2. Natural ventilation, during comfort periods with manageable humidity (with the understanding that humidity and cost restrictions may be problematic for near-term retrofit applications)

3. Superinsulation for the enclosure (roof, walls, floor, and windows/skylights), possibly to the PassivHaus standards to eliminate perimeter heat.

4. Control strategies for daylight redirection, shading and glare + cooling and ventilation, with expert recommendation/feedback to enable the occupant/user to make better decisions for higher comfort levels and lower-energy consumption.

5. Systems integration with electric lighting and mechanical ventilation and cooling with appropriate controls to maximize the use of passive strategies.

HVAC Breakthrough Recommendations:

1) All retrofits should begin with investments in the building enclosure to maximize conservation whenever practical. The mechanical design and simulation team need to pursue
the optimal cost-effective levels of wall, roof and floor insulation, shading, window performance, economizer and night ventilation when practical. This will be especially critical as
perimeter heating units are being replaced in existing buildings. The lack of insulation behind
these units, and the poor quality of windows and walls above these units must first be addressed to ensure the appropriate sizing of perimeter HVAC units after conservation.

2) Major HVAC retrofits should be designed to separate thermal conditioning from ventilation air delivery to ensure the highest level of user control for energy efficiency and comfort without compromising air quality, and to maximize the use of economizer without compromising energy.

3) HVAC retrofits should consider local control, to a level where each occupant has thermal control, possibly by separating ambient conditioning, related to air quality and broad thermal comfort requirements, from task conditioning for individual comfort during the times that the occupant is in residence. This is similar to separating ambient and task lighting, by which much less energy intensive conditioning is provided for the majority of spaces and time periods, with on-demand task levels through innovative technologies and systems. Questions not answered but that require further investigation include: (1) Should unoccupied spaces be conditioned to the same level as occupied spaces? And (2) Should air locks and stairwells be conditioned at all?

4) A recommendation identified during the lighting workshop included a possible recommendation for HVAC as well. The group recommended further discussion of a transformational shift in the procurement of systems from component purchases for site assembly to integrated product delivery for performance – a shift that is equally applicable to heating, cooling and ventilation delivery. This demands a new business model with Request For Proposals (RFP) that request bids for integrated systems that perform to standards – pushing the HVAC component industry to collaborate to deliver plug and play solutions. An example to this "single point of responsibility" is the Carrier France delivery of thermal comfort and air quality with major energy savings and the highest level of user and Facility Manager satisfaction for the SARI Development company in numerous high rises in Paris.

Lighting Breakthrough Recommendations:

1) All lighting retrofits must shift away from conventional combined task ambient lighting to separate ambient and task lighting where applicable. This implies significantly lower ambient lighting levels (200 lux or less) with all higher light levels provided by the most efficient task sources with significant "time off." This supports measurably higher levels of daylight utilization for both ambient and task, and reduces lighting energy use at least 50% from present levels.

2) Lighting performance metrics for projects and building codes must shift from connected energy loads - the typical watts per square foot - to operational energy use with kWh/occupied hours as a metric. With this metric, the location of fixtures, their efficiency and effective distribution of light on task, their interface with daylighting, and their controls will be the measure of performance.

3) The expert workshop discussed a transformational shift in the procurement of lighting away from component purchases for site assembly to integrated product delivery for guaranteed system performance. This demands a new business model with RFPs that request bids for integrated systems that verify they can perform to standards – pushing the lighting component industry to collaborate to delivery plug and play solutions (imagine a daylight sensor that actually opens the blinds when you want).

Advanced Predictive Control Framework Breakthrough Recommendations:

1) Conventional building control systems operate the heating, ventilating, and air conditioning on a fixed schedule, based upon anticipated occupancy and use of the building. A novel control method is proposed for integrated building heating, cooling and ventilation control to reduce energy consumption and maintain desired indoor temperature set points. It adopts the Model
Predictive Control framework which integrates local weather forecasting (temperature, solar
radiation and wind speed) with occupant behavior detection (number of occupants and occupancy duration) The weather forecasting will be based on micro climatic data collected from a locally installed weather station, while occupancy behavior will be derived from indoor temperature, relative humidity, CO_2, lighting, motion and acoustics data gathered from environmental sensors within the building. Advanced control systems can also support an unprecedented level of passive conditioning and occupant controls for energy efficiency.

Performance Metrics and HVAC Systems Specifications

The Carnegie Mellon team compiled the Expert Workshop results many months before the PSU hired the building 661 design team. Once the core integrated design team had been hired, the building systems specification effort began between the EEB Hub members and the design team. First, a workshop was held to revisit the Expert Workshop results, and following that a series of workshops devoted to technology specification that included several of the EEB Hub building systems technology researchers, some private industry consultants, the project's architects, engineers, project manager, construction management team, and energy modeling and lighting consultants.

This goal setting was contextualized within the intentions of the overall project. The desire to establish ambitious energy efficiency performance metrics needed to be balanced with the project's values of Repeatable Demonstration, Systems Integration, and Cost Certainty. The team assembled developed a set of relative and absolute performance metrics for the project. Some of these are due to standard metrics from the client, such as Pennsylvania State University's requirement for 30% savings compared to ASHRAE 90.1-2007 for their all building construction projects. The Hub defined a goal to achieve Energy Star rating of 75 or higher (to be 50% better than a typical comparable building), and finally the team established a Proposed Design EUI of 40 kBtu/sf-year. The final performance modeling results anticipate that these goals will be well exceeded in the final result.[27]

The project values all impinged upon the systems specifications as well. At the time of the technology specifications, the KT had come up with a set of preliminary zoning options. A uniform desire to demonstrate multiple repeatable integrated in themselves mechanical system solutions within this relatively small building (approximately 38,000 sf). And, as with the performance goals they adopted for the project, the designers, engineers, constructors, and their EEB Hub consulting researchers maintained the notion of scalability, repeatability, and availability of the technology they selected for the building. For instance, one of the main topics of discussion was whether or not to consider ground source heat pump. While this is an extremely energy efficient technology, there was concern present among the group that it is not as scalable as it would need to be in order to be included. Questions also arose about how to subdivide the building into zones. At the end of one of the first systems specifications session that included both the EEB Hub researchers and the design team, three zones and their accompanying mechanical system profile had been outlined. See Figure 17 below.

Area	Vent	Heat	Cool	Distribution
1 High Bay	Rooftop dedicated outdoor air ventilation system for humidity control, pressurization, and some temp control.	GCHP	GCHP	Units Ducted local to space (UFAD for Mezz)
		Hi eff Boiler	Air cooled chiller	Chilled Beam
				FCU
2 HeadHouse 2nd Flr	Rooftop unit for outdoor air, pressurization, heating, and cooling.	Rooftop unit with gas fired furnace possibly supplemental terminal heating	Rooftop unit with chilled water coil.	UFAD or Displacement VAV
				FCU
3 HeadHouse 1st Flr	Natural Vent	Air side heat-pump with VRV for main plus hot water convectors as back-up	Air cooled condensing unit with VRV	VRV

Figure 23: First Draft Mechanical System Profile (Bruce Brooks & Associates)

[27] (Atelier Ten, 2012)

Energy Modeling

Energy modeling occurred at three phases in the design, at Criteria Design, early Design Development and Implementation and later Design Development and Implementation.[28] At each phase, the systems and decisions became more concrete. The first model established a baseline condition; they used ASHRAE standards for a commercial office building with a type 5 system with a reheat. Since the building was not occupied, only some details were modeled from the existing conditions and others came from standardized assumptions. For instance, the baseline energy model included insulated walls, even though the walls in building 661 aren't insulated in the existing condition. The baseline model had a great deal of detail, because the design team had a good set of drawings from PIDC.

Each energy modeling iteration allowed the team to get a finer grain of detail to compare alternates to the base energy model in terms of energy performance. These steps also allowed the design team to register the design options against their energy target goals, the 30% below ASHRAE 2007 90.1 and Energy Star 75 or better. Before each energy model run, A10, the client, and the designers would make recommendations on what to model. The model evaluated what the impact of any EEM would provide and a payback curve for the different technologies. The curves allowed the team to evaluate the energy improvement vs. the cost. For the Hub, there were several factors to evaluate for these decisions. The three HVAC subsystems had a high demonstration value for the project, but other options were judged independently according to their cost effectiveness. Since the EEB Hub did have these systems they wanted to demonstrate, there were fewer remaining open-ended options for the design team to evaluate through the energy model.[29]

Schematic Design Phase Energy Model

- Add R-20 insulation to currently un-insulated walls, pending results of upcoming wall moisture and freeze/thaw studies
- Increase roof insulation to R-40
- Consider triple glazing
- Reduce lighting power densities at least 20% below ASHRAE 90.1-2007 maximum allowed
- Discuss the feasibility of naturally ventilating high bay area
- Add exhaust air energy recovery (enthalpy wheels) to air handling units

[28] (American Institute of Architects, 2007)
[29] Appendix E: Schematic Design Energy Analysis Report, Atelier 10; Appendix F: Developed Design & Implementation Phase Energy Analysis Report, Atelier 10); Appendix G: Developed Design & Implementation Phase Final Energy Analysis Report, Atelier 10

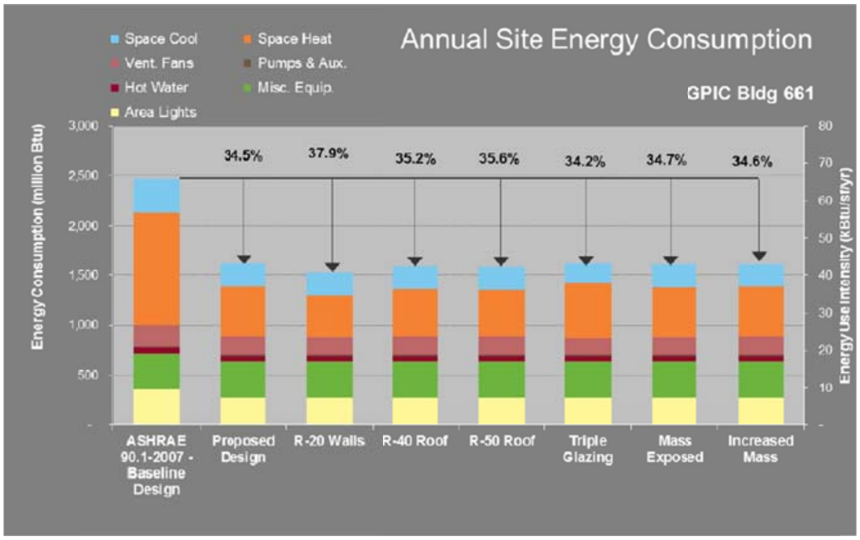


Figure 24: April Energy Model Envelope Options (Atelier 10)

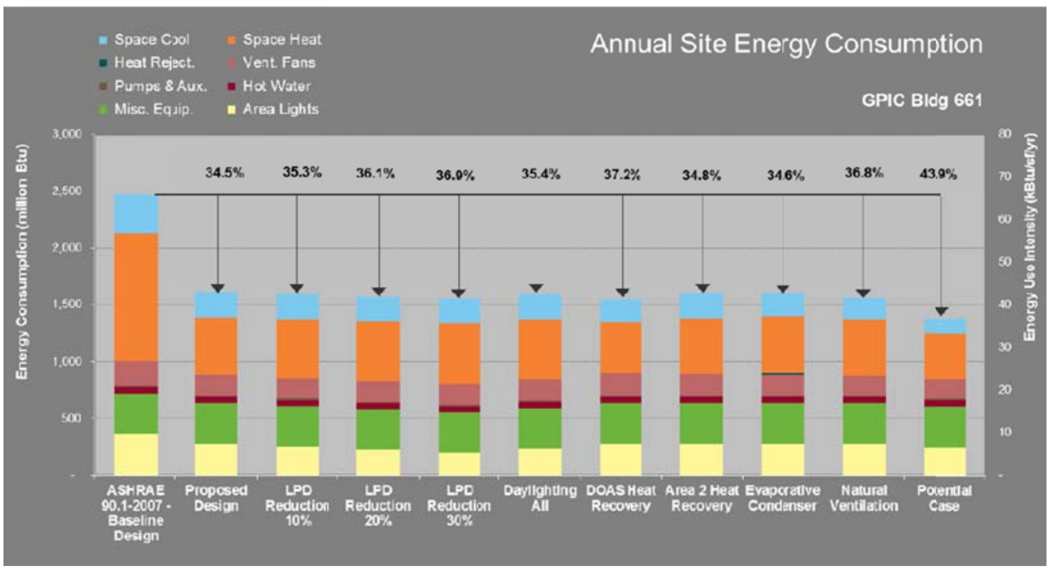


Figure 25: April Energy Model Lighting and HVAC Options (Atelier 10)

Design Development and Implementation Energy Model

- The following options were evaluated in order to test their effect on building energy performance
- Adding external shading to skylights and south windows with VE-12M glass (SHGC: 0.37)
- Adding external shading to skylights and south windows with current Solarban 70XL glass (SHGC: 0.27)
- Solar collectors for domestic hot water with electric heat backup
- Solar collectors for domestic hot water with natural gas backup
- Indirect-direct evaporative cooling at DOAS and/or rooftop units

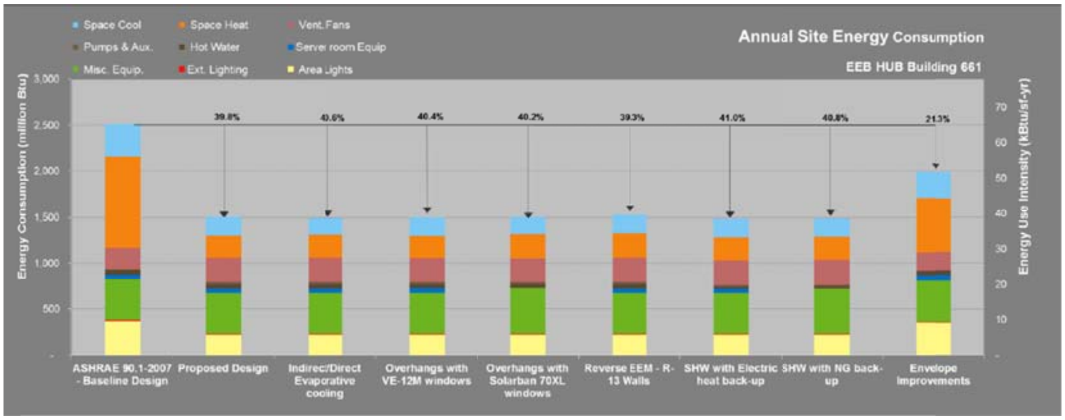


Figure 26: August Energy Model Solar Shading and Solar Hot Water Options (Atelier 10)

Design Development and Implementation Final Energy Model

The October energy model incorporated the following changes from the August energy model:

- The envelope infiltration rate changed from 0.1 cfm/sf (very air tight building) to 0.4 cfm/sf for Baseline Proposed Designs. And the actual envelope infiltration rate data has been used for a second baseline
- building and compared against better target infiltration rates
- The current model has a LPD reduction of 8.5% compared to 32% considered in the preliminary model
- DX cooling removed from DOA unit (now the system has 100% chilled water cooling)
- The revised fan power for RTU's, FCU's and VRV's are lower than the preliminary model
- The overall wall construction changed from R-20 to R-24
- The current model includes vacancy sensors (represented as a 13% LPD savings) whereas the previous model
- represented them as occupancy sensors (represented as 10% LPD savings).
- Trees have been modeled on the South and East side of the building to account as exterior shades
- High performing Solarban 70XL glazing removed from North skylight (existing skylight to remain).

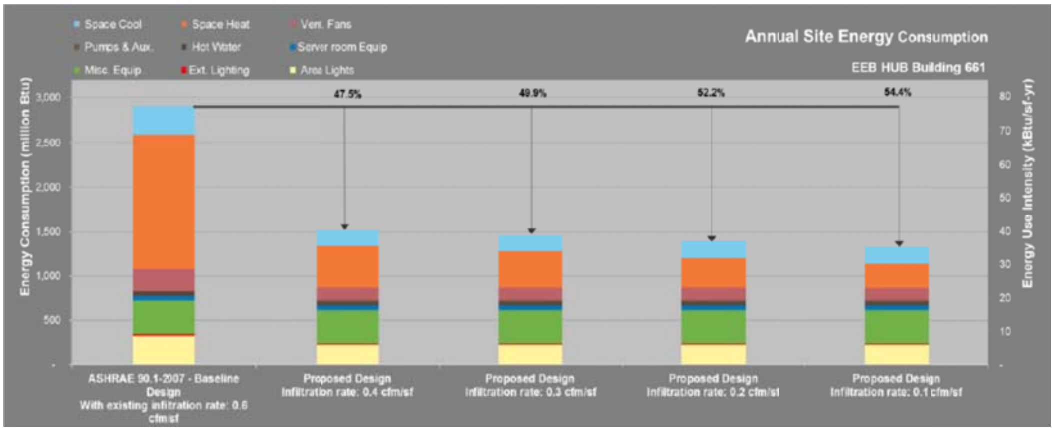


Figure 27: October Energy Model Envelope Infiltration Conditions (Atelier 10)

Building 661 Design:

Space Programming and the Existing Structure

The building is divided into two main parts and three mechanical systems zones (as discussed in the performance metrics and systems specification section). The “head house”, the horizontal bar space at the front of the building, and the much larger “high bay” space in the rear. The placement of the programs to be supported within building 661 responds the the physical givens of both of these areas. For comprehensive retrofits, like building 661, a project may pursue reprogramming the spaces to explore the ways the program placement can link to the energy goals of the project.

Several of the project values were implicated in the space programming process (the spatial arrangement and placement of different programs). The repeatable demonstration, learning, and the collaborative environments values in particular register in the arrangement of space and function within building 661. The way the program responds to the physical givens of the building and takes advantage of the existing structural and envelope conditions is one of several architectural and engineering repeatable demonstration lessons of the project. The design takes advantage of the existing light and dark areas of the building (ones with access to daylight through the envelope and ones without) with the programs that would benefit from those respective conditions, as in light functions and dark functions.

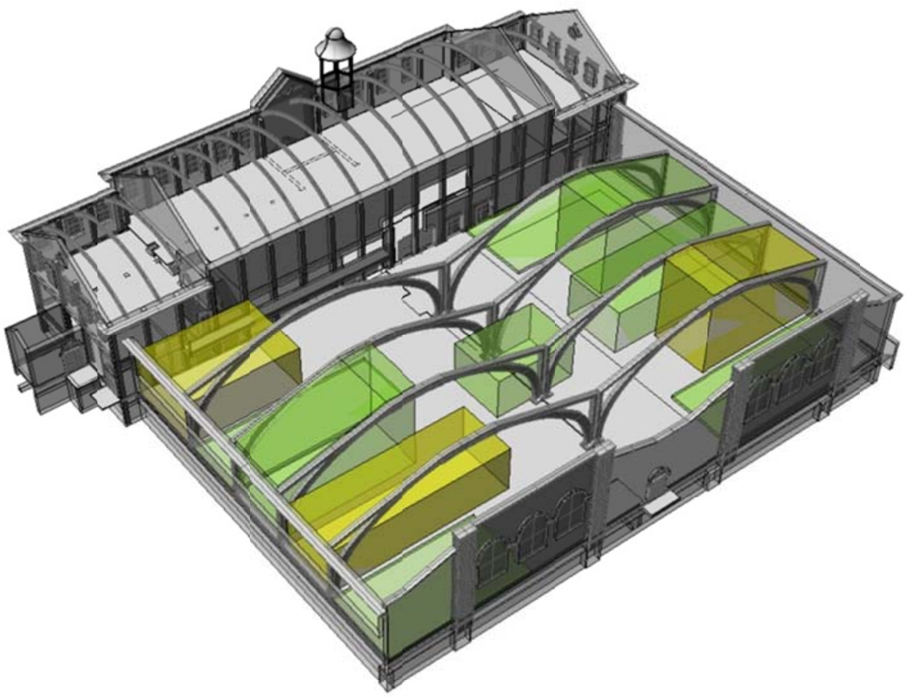
Further, the design uses the structural “bones” of the building; this is effective with the decision to establish an order for dividing collaborative working rooms and integrated systems labs according to the glue laminated arches which cut across the high bay space- see Figure 22. This allows the workrooms and labs to create a glazing/envelope design that responds to these structural lines, as they do in the existing building. The same principles are at play in the head house portion of the building, as the concrete masonry structural columns form a grid whose bays run perpendicular to those in the high bay space are capped with similar laminated wood beams at the roof line. This grid is used to establish the server and office partition walls on the second level of the building. In the building 661, this will allow building inhabitants who need access to natural light for their work and functions to have it and those who need to block daylight out to do that as well.

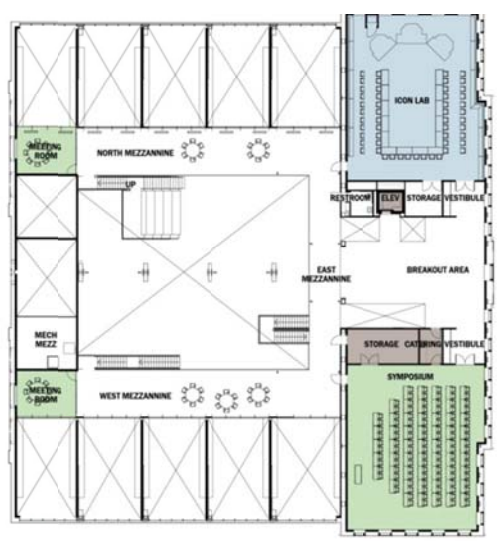
Head house programming:

- The telepresence room with room-size teleconferencing equipment is located in the darkest area of the head house. Also in this “dark zone” are restrooms, electrical room, and the server room. All of thes activities either benefit from an exclusion from daylight or require access to daylight the least. Figure 23
- The administrative offices and the common breakout area on the second level between two administrative office wings. These functions benefit from daylight and gain access to natural light from either the west-facing punched windows on the front of the building or the inserted clerestory window that looks out onto the roof of the high bay space. Figure 23
- The ICON Lab and the Symposium space programs are located on the first level of the head house, both of which both have heavy mechanical equipment and benefit from the ability to eliminate natural light. Figure 23
- The lobby is located in the head house. It allows visual access to the high bay space so you can see the main circulation stair to the second level.

High bay Programming

- Workrooms situated across from one another with the large atrium space in between and align with the bays established by the wooden arches that run across the space. This entire high bay space has a great deal of visual access and access to natural light. A visitor can see into the workrooms and labs. And those in the labs can see across to the other side of the building. Figure 24
- Integrated systems labs are also located within this space at the corners. Figure 23
- The central atrium space will host exhibits, gatherings and spaces for breakout meetings.
- The mezzanine level will provide more work areas and a way to view the lab and workroom activity. Figure 23





- PRIVATE OFFICES & MEETING
- SYMPOSIUM AND CONFERENCE
- RESEARCH LABS / WORKSPACE
- SUPPORT SPACES & MECHANICAL

Figure 30: Rendering 661 (Kieran Timberlake)

Figure 31: Rendering 661 (Kieran Timberlake)

Building Subsystems Design and Engineering

Following the model developed during the Expert Workshop, this section is devoted to the final design features of building 661. A description of building 661's subsystems follows below to give you a detailed sense of some of the decisions as they relate to energy efficiency specific building features and technologies. This information is not in exhaustive, but it summarizes the design team's reflection on different energy efficiency-related building design decisions. Information was gathered from key informant interviews with the design team and also from the Building 661 bid drawing set and bid documents.

Enclosure

- Envelope tightness: The architect considered the existing conditions and what type of insulation would yield the best result. The designers weighed several factors- the building's blower door test revealed a high air infiltration rate that pointed to a leaky envelope; 661 is registered as a historic structure, so attaching insulation to the exterior is not an available option. These factors led the design team to select spray foam insulation because of capacity to deal with a lot of different conditions. It will work on the interior of the envelope in the wall assembly to close the ceiling to the wall.

- Masonry walls and exterior trim: The design selectively restores and replaces exterior trim elements as well as areas in the cracking brick masonry. The remaining exterior brick masonry will be cleaned.

- Glazing: Almost none of the original glazing is intact in 661. Original openings have suffered due to the brick and glass block infill. The design plans to reinstate many of these openings in the building envelope. Additional openings have been created at the labs in the back of the structure. Low-e, argon and aerogel-filled, double glazed window assemblies are specified for the head house and the high bay portions of the buildings. The design includes no triple glazing. The lab and head house windows will have a manual roller shading system. The design specifies a combination of wood and aluminum framed windows. All existing windows will be replaced, and as mentioned, several new windows will be installed in currently brick and glass-block infilled areas. The design team established the goal that 90% of all spaces be naturally daylit, so the building is not overglazed.

- Interior wall insulation selection: The building's blower door test revealed a high air infiltration rate that pointed to a leaky envelope, so infiltration of exterior air informed the infiltration selection type. Additionally, 661 is registered as a historic structure, so attaching insulation to the exterior is not an available option. Closed-cell spray foam insulation will be used on the interior walls in both the head house and the high bay space insulation assemblies. Sprayfoam has the capacity to deal with lots of different conditions, and in 661, it will allow the building to be very tightly connected where the wall meets the ceiling. The design specifies insulation value R-24 for the walls.

- Attic space in the Head house: The design presented another insulation problem to solve in the attic space in the Head house. The question arose whether or not to condition the attic space or not and where to place the insulation, because mechanical systems needed to be in that space. The underside of roof is a concrete plank on wood purloins and the designers questioned whether the dew point would occur some point within the thickness of that assembly and have a degrading effect.

By specifying an-open cell insulation on the underside of the roof, it allowed mechanical systems in the attic space. The insulation level for this space is R-30.

- High bay roof replacement: The high bay roof construction is also constructed of concrete planks on wood purlins. The High bay concrete planks suffer from damage in an estimated 10% of the planks. There is indication that water may be coming through the joints, and some planks are spalling. The design team weighed two options for the replacement of the roof.[30] The first option would be to replace the damaged concrete planks in the high bay. The second option was to replace the entire roof with Structurally Insulated Panels (SIPs) of varying insulation levels (R-30, R-50, or R-60). The design team decided to replace the entire high bay space with T-30 level SIPs due to the schedule uncertainties with going the repair route. This choice also led to a significant energy performance benefit, though the design team determined that increasing the SIP insulation value to R-50 or R-60 was not worth the additional cost.

[30] Appendix C: 661 Roof Structure – Head House ; Appendix D: 661 Roof Structure – High Bay

HVAC

The selection of the mechanical systems for 661 involved collaboration between the design team (and specifically the Mechanical, Electrical and Plumbing consulting engineer, Brooks Brooks & Associates) and the consulting researchers at the Energy Efficient Buildings Hub—see section on Energy Efficiency Technology Specifications and Performance Goals. The resulting design involves three different heating, cooling, and ventilation strategies in one building that will be installed in three different "zones" of the building- see Figure 15. The first philosophy uses moving water to provide thermal comfort. The second involves moving air with displacement distribution. The third uses d a ductless split system with no ductwork. The second and third systems are very scalable for buildings with packaged Roof Top Units. For buildings that have existing boilers and pipes that move water, the ductless split system is appropriate because the building won't have to add in ductwork. The system that is the most radical for the US building market is the chilled beam and radiator system. This system is very common in Europe.

ZONES	EXISTING GROSS AREA (incl. ext. wall)	EXISTING NET AREA (excl. ext. wall)	RT @ 500 SF / RT
Zone 1 North High bay	8,529	8,284	17
Zone 2 South High bay	8,529	8,284	17
Zone 3 North 2 Story	8,101	7,550	15
Zone 4 South 2 Story	8,101	7,550	15
TOTALS	**33,259**	**31,668**	**64**

- Area 1: The first and second level of the High bay space and the mezzanine level of the Head house will employ an active and passive chilled beam system that provides sensible cooling and radiator hot water heating. Fan coil units provide heating and sensible cooling for the mezzanine area. Ventilation for these spaces will be provided by a dedicated outdoor air unit with desiccant dehumidification to meet ventilation requirements and latent loads. An important design feature of the mezzanine is that it will allow access to the systems contained within for future tuning. It also assists to close the glazed lab fronts to the roof structure. See Figure 27.

- Area 2: The first and second level of the Head house space will use packaged Variable Air Volume (VAV) rooftop units with DX cooling and gas furnace heating in addition to radiator hot water heating in perimeter zones. There will also be VAV terminal boxes for 1st Level zones. The distribution of the air will use the under floor plenum with displacement diffusers on the 2nd level of Head house, the iCon lab, and the symposium. Overhead mixed distribution for most of the spaces.

- Area 3: The second level of the Head house will use variable refrigerant volume units with natural ventilation.

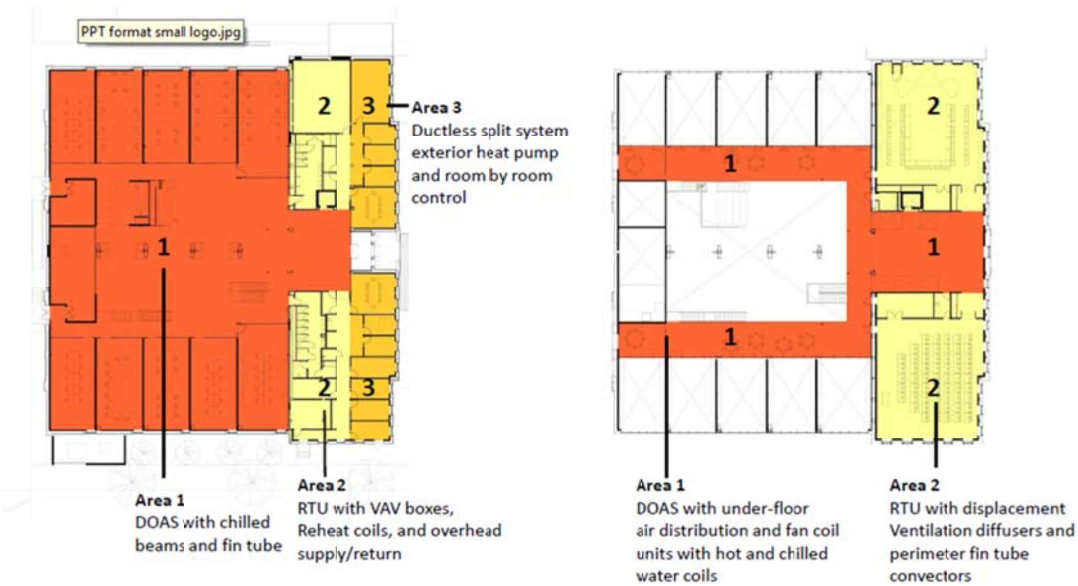


Figure 32: The First and Second Level Mechanical Zones (Kieran Timberlake)

Figure 33: View in the High Bay Space: Mezzanine Level, Lab, and Skylight Rendering (Kieran Timberlake)

Figure 34: View in the Head House Space (Kieran Timberlake)

Lighting

As discussed in the Spaces Programming section of this report, this building has two distinctive kinds of space particularly with respect to access to natural light. The lighting character of the Head house space is determined by the existing punched windows in the façade; whereas the lighting in the High bay space will undergo a dramatic transformation with the reinstatement of many of the building openings in the process of the retrofit. The team adopted a goal of 90% of the spaces in the building need to be naturally daylit, a requirement for a LEED point that relates to the guidance from the expert workshop report. The building also had ambitious lighting power density goals.

- Programmatic Access to Natural Light: The design team's mandate from the EEB Hub's Expert Workshop Report guided them to tackle the passive moves for the building first in this case of comprehensive, deep retrofit. The design team fit the program according to the lighting requirements and space needs. The programs that needed to block access from natural light was palced in the dark part of the building. See Figure 29 for a lighting analysis of level 1.

- Lighting in the labs and offices: These rooms will have access to natural light and have been designed to eliminate the need for artificial lighting. These windows will all have manual roller shades and the rooms artificial lighting assemblies will be managed by a dimmable ballasts. These respond automatically to lighting sensors which adjust according to the available daylight entering the rooms. See Figures 34 and 35.

- Skylight Replacement: One skylight will be replaced and one will remain. Though these features will be slightly different from one another as a result, this decision to keep the skylight nearest to the north side of the building related to the fact that it still will be fuctional for several more years. Both skylights will have manual roller shades installed.

- Clerestory window addition: The lighting level analyses revealed that the darkest area in the building is the second level mezzanine space. A new clerestory window allows a view onto the roof of the High bay space from this mezzanine level area. Figure 32 shows the clerestory addition. Figure 33 looks into the space that will be granted access to the natural light with the clerestory in the background.

- Lighting Power density: The project modeled the lighting power density at 10%, 20%, and 30% below an ASHRAE 2007 90.1 baseline.[31] The final design maintains an 8.5% reduction below the baseline in LPD overall in the building. The installed lights are amiz of linear fluorescent and LED task and ambient lighting.

[31] Appendix E: Schematic Design Energy Analysis Report, Atelier 10.

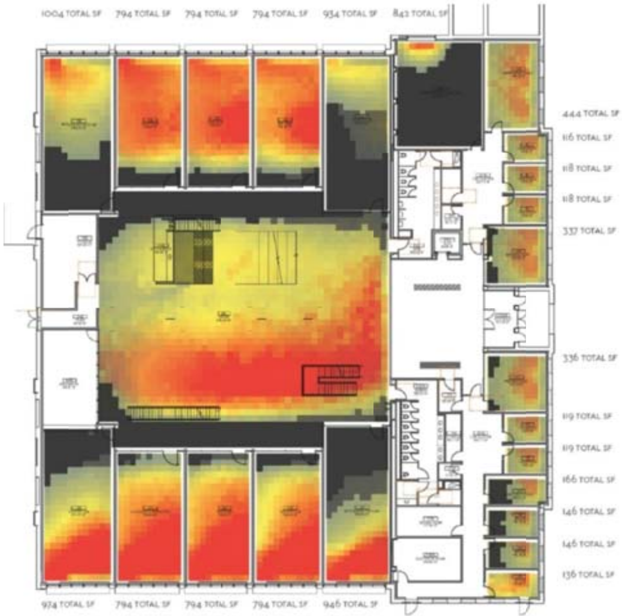


Figure 35: Lighting Level Analysis September 21st at 9 am and 3 pm (Kieran Timberlake)

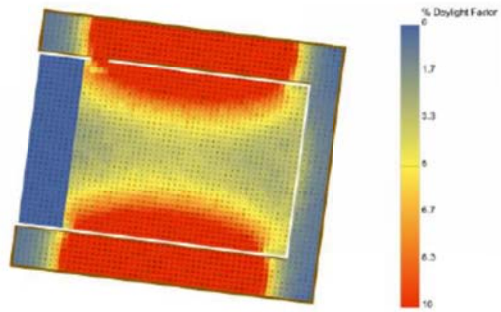


Figure 36: Daylight Factor Nodes Analysis (Kieran Timberlake)

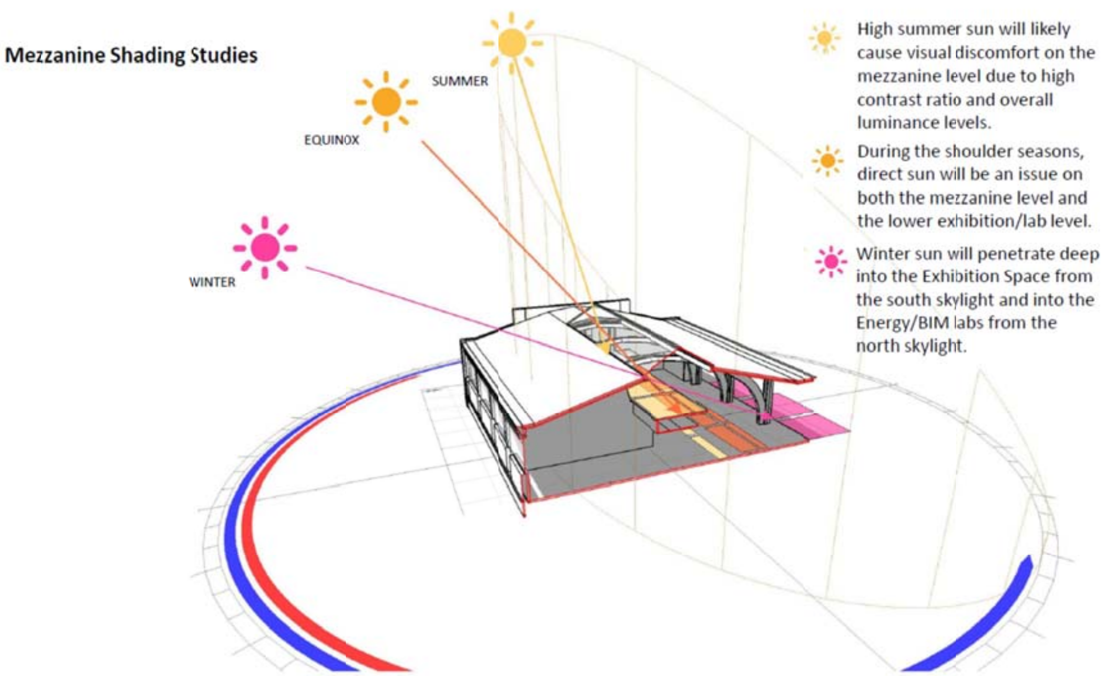


Figure 37: Shading Studies (Kieran Timberlake)

Figure 38: View in the Mezzanine Looking Out Inserted Clerestory Window (Kieran Timberlake)

Figure 39: View into the Head House Mezzanine Area; Clerestory in the Background (Kieran Timberlake)

Figure 40: View in the Labs Looking Out (Kieran Timberlake)

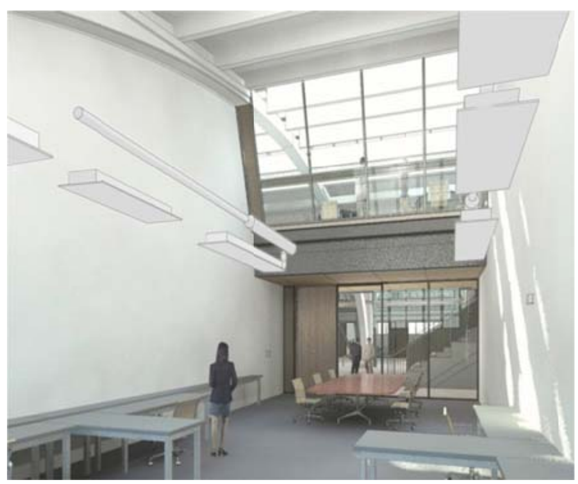


Figure 41: View in the Labs Looking In (Kieran Timberlake)

Sensors and Controls

All technologies specified in building 661 were meant to be "state-of-the-shelf" scalable technologies that could be incorporated without an unreasonable cost burden. Because of this, the sensors and control scheme employed in building 661 is imminently scalable technology without motorized assemblies. The main sensors and controls features are a granular mechanical zoning strategy and artificial lighting that respods to a natural light sensing network.

- Mechanical system zones: The building will be divided into three mechanical system zones. Within each of those three zones, additional zoning allows for individualized control of those environments. Each zone will have individually addressable heating, cooling, ventilation, lighting and individually addressable plug loads. See Figure 38, and 39 for the micro-zoning plan of building 661

- Vacancy Sensors: Most spaces in the building have vacancy sensors that will power off the lighting systems when vacant.

- Lighting Sensors: Both the fluorescent and LED lights specified for this building have individual ballast responsive capabilities that will allow each unit to respond to occupancy, lighting levels and load shed commands. See Figure 36 for lighting networking diagram examples.

- The building will be scientifically instrumented providing a minimum of the following sub-metered data for each zone: IEQ levels for dry bulb, RH, CO_2, CO, particulates, TVOCs, light level, and noise.

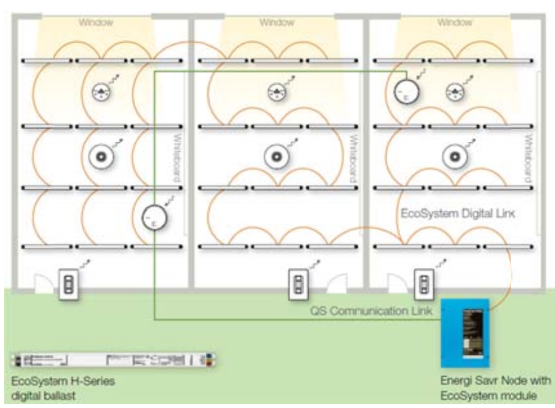


Figure 42: Lighting Network (Atelier 10)

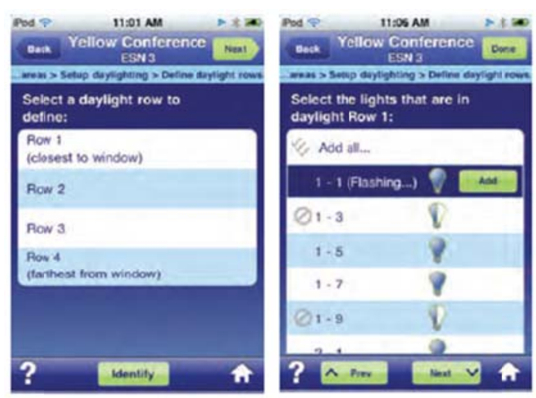


Figure 43: Example Lighting Controls (Atelier 10)

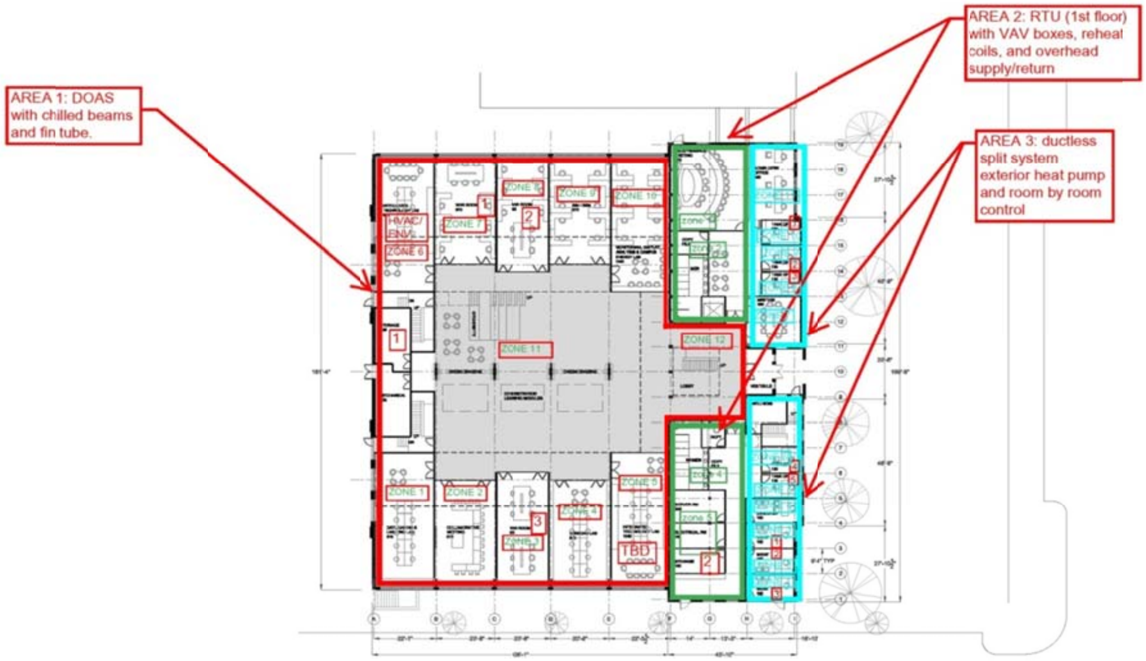


Figure 44: Level 1 Zoning Plan (Bruce Brooks & Associates)

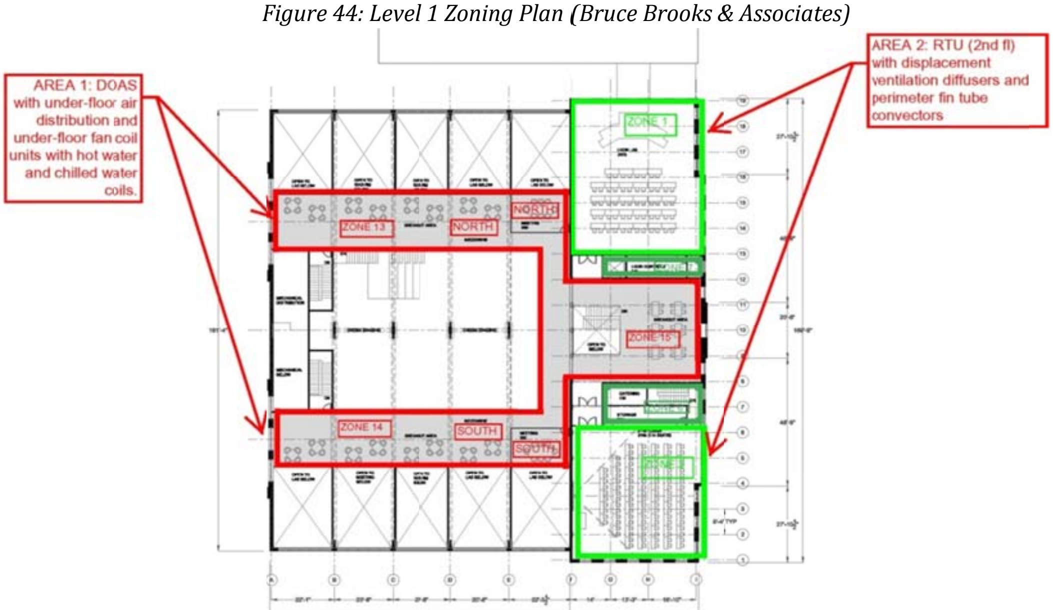


Figure 45: Level 2 Zoning Plan (Bruce Brooks & Associates)

Works Cited

Adept Management Limited. *Adept Management Limited.* January 14, 2013. http://www.adept.com/ (accessed January 14, 2013).

American Institute of Architects. "Integrated Project Delivery: A Guide." *American Institute of Architects.* 2007. http://info.aia.org/SiteObjects/files/IPD_Guide_2007.pdf (accessed January 1, 2013).

Atelier 10. *Developed Design & Implementation Phase Energy Analysis Report.* New Haven: Atelier 10, 2012.

Atelier 10. *Schematic Design Energy Analysis.* New Haven: Atelier 10, 2012.
Atelier Ten. *Developed Design & Implementation Phase Final Energy Analysis Report.* New York: Atelier Ten, 2012.

Ballard, Glenn and Hall, Gregory. "Towards Construction Just in Time." *Proceedings from ARCOM Conference, Association of Researchers in Construction Management.* Sheffield, UK: ARCOM, 1995. 1-11.

Ballard, Glenn. "Project Production Systems Laboratory." *Target Value Design.* May 6, 2006. http://p2sl.berkeley.edu/2009-05-26/Glenn%202008-07-29%20=%20Target%20Value%20Design.pdf (accessed January 8, 2013).

Ballard, Glenn, Lauri Koskela, and Veli-Pekka Tanhuapää. "Towards Lean Design Management." *Proceedings 5th Annual Conference of the International Group fro Lean Construction, Griffit University.* Gold Coast: Griffith University, 2007.

Better Bricks. *Better Bricks Case Studies.* 2012.

http://www.betterbricks.com/healthcare/case-studies (accessed 2013).

Choi, Christopher. "Removing Market Barriers to Green Development: Principles and Action Projects to Promote Widespread Adoption of Green Development Practices." *Journal of Sustainable Real Estate*, 2009.

Department of Energy. "www.gpic.org." *Greater Philadelphia Innovation Cluster.* 2010. www.gpichub.org (accessed 2013).

ICF International and National Association of Energy Service Companies. *Introduction to Energy Performance Contracting.* Commissioned Report, Washinton, DC: US EPA, 2007.

Lean Construction Institute. *Lean Construction Institute.* January 1, 2013. http://www.leanconstruction.org/readings.htm.

Leavitt, Josh, John C. McIlwee, and K&L Gates. "Navigating State Design Build Statutes in the Wake of a "Turned Federal Battleship"." *Building Better Construction Contracts: Tailoring Incentives, Creating Collaboration and Developing Effective Risk Allocation.* New York City: Practising Law Institute Symposium, 2011.

Loftness, Vivian, Azizan Aziz, Khee Poh Lam, and Steve Lee. *Expert Workshop Report.* Philadelphia: Department of Energy, 2011.

National Park Service. *Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings.* http://www.cr.nps.gov/hps/tps/standguide/rehab/rehab_index.htm (accessed January 2013).

National Renewable Energy Lab. *Using an Energy Performance Based Design-Build Process to Procure a Large Scale Low-Energy Building Preprint .* Conference Paper, Las Vegas: NREL, 2011.

New Buildings Institute. *Getting to 50 and Beyond.* 2012. www.newbuildings.org (accessed 2013).

United States Department of Energy. *Blower Door Tests.* April 2012. http://energy.gov/energysaver/articles/blower-door-tests (accessed January 2013).

—. *Zero Energy Buildings Database.* 2008. http://zeb.buildinggreen.com/ (accessed 1 3, 2013).

Whole Building Design Guide. *Whole Building Design Guide.* January 1, 2013. http://www.wbdg.org/ (accessed January 1, 2013).

Appendix A: Collaboration Addendum, V6.0

OPP COLLABORATION ADDENDUM, V6.0

Energy Efficient Building (EEB) HUB – Building 661 Renovation and 7R

1 GENERAL

1.1 Intent of Collaboration

The likelihood of a successful project will be increased by promoting the following objectives: all members of the Project Team collaborating throughout design and construction with all other members of the Project Team; planning and managing the Project as a network of commitments; optimizing the Project as a whole, rather than any particular piece; and tightly coupling learning with action to promote continuous improvement throughout the life of the Project.

By forming a collaborative Project Team, the parties intend to gain the benefit of an open and creative learning environment, where members are encouraged to share ideas freely in an atmosphere of mutual respect and tolerance. Project Team members shall work together and individually to achieve transparent and cooperative exchange of information in all matters relating to the Project and to share ideas for improving project delivery. Team members shall actively promote harmony, collaboration and cooperation among all entities performing on the Project.

1.2 Definitions

A. **Integrated Project Team:** The Project Team consists of a designated representative from the Owner, the Design Professional and Consultants, the Construction Manager and Consultants that are participating in this Collaboration Addendum. Trade Contractors will designate representatives upon completion of design and subsequent bid and award of the construction work, each firm should assure that its Project Team representative attends all Project Team meetings, has authority to act on behalf of the firm, and fulfills his or her responsibilities as a Project Team representative.

Table 1-1: Project Team representative contact information

Role	Firm	Representative	E-mail	Phone
Owner	Penn State OPP	Steven DiBartolo	Svd12@psu.edu	215-557-3279
Architect	Kieran Timberlake	Johann Mordhorst		
Construction Manager	Balfour Beatty	Amanda Goolsby (D) Greg Nowell (C)		
Commissioning	Aramark			
DESIGN PHASE				
Environ and Consultant	Atelier Ten	Paul Stoller		
MEPF Engineer	Bruce Brooks Assoc.	Joseph Matje		
Struct. Engineer	CVM	Rob Schaeffer		
Civil Engineer	Hunt Engineering			
Landscape Design	Bryan Hayes Studio			
Acoustics	Metropolitan Acoustics			
Mechanical Specialist	EMS			

Electrical Specialist	MC Dean			
CONSTRUCTION				
Abatement	TBD			
Demolition	TBD			
General Construction	TBD			
Mechanical	TBD			
Electrical	TBD			
Plumbing	TBD			

B. **Executive Team:** The Executive Team consists of designated representatives from the Design Professional, the Construction Manager and the Owner that meet quarterly and for special meetings to resolve decisions escalated from the Project Team level.

Table 1-2: Executive Team representative contact information

Role	Firm	Representative	E-mail	Phone
Owner	Penn State OPP	Greg Scott		
User	EEB	James Freihaut		
Designer	Kieran Timberlake	David Riz		
Construction Manager	Balfour Beatty	Bevan Mace		

C. **Conditions of Satisfaction:** A set of performance criteria established by the Project Team.

1.3 Reliable Promising

Fundamental to the success of the Project is the willingness and ability of all Project Team members, including the Owner's Representative and Project Stakeholders, to make and secure reliable promises as the basis for planning and executing the Project. In order for a promise to be reliable, the following elements must be present:

A. The conditions of satisfaction must be clear to both parties – the performer and the recipient of the promise.
B. The performer is competent to perform the task or has access to the competence to perform the task and the wherewithal (materials, tools, equipment, instructions).
C. The performer has estimated the time to perform the task and has internally allocated adequate resources and has blocked the time on its internal schedule.
D. The performer is sincere in the moment that the promise is made – only making the promise if there is no current basis for believing that the promise cannot or will not be fulfilled.
E. The performer is prepared to be accountable if the promise cannot be performed as promised and will promptly advise the Project Team if confidence is lost that the task can be performed as promised.

1.4 Collaboration

In order to achieve the Owner's objectives, design of the Project must proceed with informed, accurate information concerning program, quality, cost and schedule. While each Project Team member will bring different expertise to each of these issues, all of these issues and the full weight of the entire team's expertise will need to be integrated throughout the entire process if the value proposition is to be attained. None of the parties can proceed in isolation from the others; there must be deep collaboration and ongoing flow of information.

The parties accept the relationship of mutual trust and confidences established with each other by these principles, and promise to furnish the necessary skill and judgment and to collaborate and cooperate with each other and with other Project participants in actively pursuing an integrated project and furthering the interests of the Project. The parties each recognize that their opportunity to succeed on the Project is directly tied to the performance of other Project participants. The parties shall therefore work together in the spirit of cooperation, collaboration, and mutual respect for the benefit of the Project, and within the limits of their professional expertise and abilities.

1.5 No Partnership

By forming the Project Team and accepting these principles, the parties do not intend to create a partnership between or among any of the members, and no member shall conduct itself in any way to suggest that such a partnership exists. These principles shall not make any party responsible for the performance, nonperformance, errors or omissions of any other party.

2 COMMUNICATION

2.1 Decision Making

The Project Team will exercise its authority in the best interest of the Project and shall, to the greatest extent possible, endeavor to make decisions for the Project unanimously. In the event the Project Team fails to reach a unanimous decision, a decision may be made by majority decision and the parties will abide by the majority decision; provided, however, that an objecting party may rely on the terms of its Separate Agreement(s), including the dispute resolution terms of such agreements.

2.2 Meetings

A. Regular Meetings: The Project Team shall establish a regular meeting schedule. The Project Team shall be responsible for reviewing and stimulating the progress of the Project collaboration objectives. The Project Team shall also review the periodic Project evaluations and shall plan and implement programs to improve performance and performer satisfaction on the Project. The Project Team meetings shall be held separately from other meetings for the purpose of ensuring their importance and the candor of the exchange at the Project Team meeting. On a quarterly basis, the Project Team Meeting may include by invitation a senior management representative from the Executive Team.

B. Special Meetings: In addition to the regularly scheduled meetings, a Project Team meeting may also be set at the request of any Project Team member to address a matter of urgency. Such a meeting, to the extent possible, shall be scheduled on no less than seven days' notice, unless all Project Team members agree upon a shorter time. Notice of a special meeting shall identify the issues to be addressed, and may be held by telephone or video-conference if necessary to accommodate the urgency of the issues in question.

C. Attendance: If a Project Team representative is not able to attend either a regular or special meeting because of a scheduling conflict an alternate must be designated in advance to attend.

2.3 Communication Procedure

The Project Team shall establish communication procedures for the Project. If the procedures permit direct communication between the Trade Contractors and Designer's Consultants (rather than such communications flowing through the Designer and Construction Manager), copies shall be provided to all Project Team members. The procedure shall also address the use of e-mail, establishment of web-based project and document management systems, production and publication of meeting minutes, and other issues relating to project communication.

2.4 Requests for Information and Submittals

The goal of collaboration, and the extensive concept involvement of Construction Manager and Trade Specialists, is to maximize the parties understanding of the design requirements, including the design intent and all technical requirements of the Project, prior to field construction. If the parties have maximized this opportunity, there will be minimal need for RFI's or clarifications after construction has commenced. The Project goal is zero RFI's and zero rejected submittals.

To the extent that the need for clarification does arise, the party seeking clarification should first raise the issue either in a face-to-face conversation, via telephone or other approved approach, in accordance with the project communication procedures. The initial conversation shall describe the issue, identify the area affected, and request the clarification needed. If the parties to that conversation are able to resolve the issue in the course of that conversation, they shall also agree on how the clarification shall be documented and reported to the Project Team in an approved report format (reference Section 6.3 for suggested reporting tools). If the parties to that conversation are not able to resolve the issue in the course of that conversation, they shall agree on how the issue will be resolved (who will do what, by when) and shall agree which of them will notify the Project Team concerning the issue and how they plan to resolve it. It is the parties' goal that RFI's will only be issued to document solutions, rather than raise questions that have not previously been the subject of a conversation. To the extent that resolution of the issue may affect progress of the Work, the issue shall be included in the planning system.

These goals should be embedded and promoted within the procurement process and execution planning for any parties joining the Project (as vendors, prime contractors or consultants).

2.5 Change Order Management

Change orders are disruptive to the planning and execution of Project work. While the need for change orders and change directives are frequently unavoidable, the goal of this Project is to minimize the disruption of these changes during construction activities and reduce the volume of change orders. To achieve this goal, Project Team members are encouraged to identify conflicts or likely changes early and resolve the plan direction with minimal impact to the Project plan.

3 PROJECT PLANNING AND SCHEDULING

Cost and schedule are design criteria. The Project Team shall establish protocols and procedures consistent with this Addendum to ensure that design proceeds fully and continuously informed by the cost and schedule implications of the design.

The planning and scheduling to be performed on the Project shall be "pull scheduling" using the Last Planner® System, or an equivalent system. In order to be pull-based, the planning system must be based upon **(a)** requests from Project Team members to other Project performers upon whom the requester's work is dependent, and **(b)** promises made by the up-stream performer about when it will finish the work to agreed-upon hand off criteria in order to enable the downstream performer to begin its performance. At a minimum the system must include a milestone schedule, collaboratively created phase schedules, look-ahead plans, weekly work plans, and a method for measuring, recording, and improving planning reliability.

3.1 Milestone Schedule

Construction Manager in collaboration with all Project Team members shall prepare a Milestone schedule for Project Team review and approval. The Milestone schedule shall include the entire Project, including both design and construction, but shall only be prepared at a milestone level. The schedule shall not extend beyond the agreed upon dates of Substantial and Final Completion and shall not replace the pull-scheduling to be done collaboratively by the Project participants.

Throughout the Project, the Construction Manager, in collaboration with all Project Team members, shall update the Milestone schedule monthly; again focusing on major milestones relied upon for tracking purposes. Construction Manager shall coordinate and integrate the Milestone schedule with the services and activities of Owner, Designer and Construction Manager. As the Project proceeds, the Milestone schedule may be updated to indicate proposed activity sequences and durations, milestone dates for receipt and approval of pertinent information, submittal of the Target Cost proposal, delivery of materials or equipment requiring long-lead time procurement, Owner's occupancy requirements showing portions of the Project having occupancy priority, and proposed dates of Substantial and Final Completion.

3.2 Phase Planning

The phase plan must be based on collaborative planning by all Project Team members who will perform in a particular phase and who, working backwards from the milestone, create collaborative phase schedules indicating when work should be done. In developing a phase schedule, Project Team members who understand how the work will be performed shall be in direct conversation with the other Project Team members from whom they will receive work or to whom they will deliver work, whether this work is physical work or information. The purpose of this conversation is to put the performers in action making direct requests and promises to each other, and specifically discussing and negotiating the hand-off criteria or conditions of satisfaction that are then mutually understood and agreed upon.

3.3 Pull-Based Design Production (DESIGN PHASE ONLY)

In order for the Construction Manager to provide full value during the design phase, it is important to develop a flow to development of the Design Documents that is based upon "Pull-based" planning. The design team must avoid "advancing" aspects of the design beyond what has been anticipated and approved for any given time period by way of the Project Team's approved planning process. Parties shall only pursue work that is shown on the applicable Project work plan as being performed in that week or that has been identified as "workable backlog" If rework is required as a result of failure to conform to the approved plan, the party that is out of compliance shall be responsible for the rework.

3.4 Look Ahead Plan

The planning system must also include use of a look ahead plan (minimum duration of six weeks or as approved by the Project Team), that identifies for each task or item of work appearing within the planning window, whether any constraints (issues that would prevent the performer from making a reliable promise that the work can be performed as indicated on the plan) exist, and if so what person has personally promised that the constraint will be removed and by when.

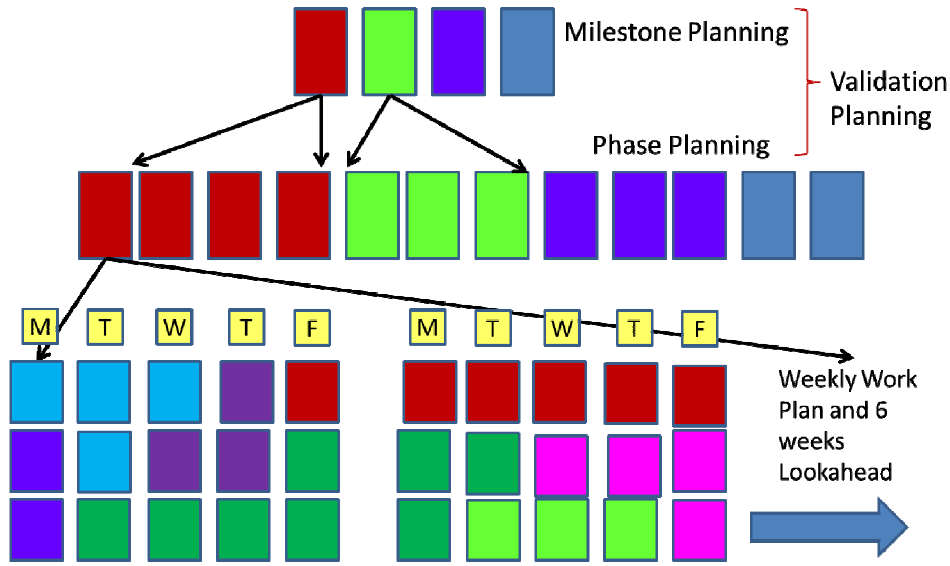
3.5 Weekly Work Planning

The planning system must also incorporate collaborative weekly work planning sessions that identify among specialists or trades, based upon the work identified in the look ahead process as constraint-free, what specific work will be completed to agreed-upon hand-off criteria (so that the follow-on task can be commenced) each day and each week. There should also be daily communication declaring what work has been completed, any variation from what was promised, and any revision for the remainder of the work plan. Finally, the system must have a method for tracking planning reliability and assessing root cause of variations for purposes of continuously improving planning reliability.

3.6 Participation in the Last Planner® System of Project Planning and Scheduling

The project will be implementing the Last Planner® System (LPS) of production control for scheduling and planning delivery of the project. All Trade Contractors and significant vendors are expected to fully participate in LPS as facilitated by the Construction Manager. Contractual expectations of the trades and vendors include:

- Full participation in all planning meetings by the appropriate level of representative of the Trade or Vendor as a member of the project team;
- The project team will:
  - validate the contract schedule with a Milestone and phase schedule developed collaboratively (usually requires Project Management level representatives) for the project to be completed within the Contract Time as defined in the general conditions of the contract;
  - engage in a highly collaborative system of planning the work in those phases with the people who manage the day-to-day assignment of work for that phase (designing the production system)(Field Level).
- The production plan for each phase will be created using the "pull" technique, starting from the milestone on the right, and working to the start of the particular phase, look ahead plan or weekly work plan toward the left.
- Optimally, the project team uses the project BIM model(s) to to optimize the design of the production system (e.g., prefabrication, systems coordination, visualization for work commitments, commissioning).
- The project team will also:
  - use a process for look ahead planning (usually 6 weeks) that identifies everything that needs to be in place so that assignments can be made and work can be done as planned;
  - use a constraints identification system to ensure quality discussions of "making work ready" and indicates that individuals have made commitments to remove constraints for tasks in future weeks 5 or 6 or beyond; and
  - engage in collaborative weekly work planning that determines the tasks that will be done in the following week.
- Tasks that are completed in the assigned week are measured, averaged each week and represented publicly in a percent plan complete (PPC) trend chart format.
- Tasks that are not completed are investigated for reasons they were not complete so that we can analyze whether the failure was one-off like weather or sickness on the job or systemic like continual failures of material to be delivered on time.
- Tasks that are not completed in a given week will be re-planned the following week in order to complete the work in a timely fashion so as not to impact the agreed upon milestone dates. The intention of the production system is to allow the Contractors to adjust their individual task time of performance without impacting the overall Contract Time.The goals are:
  - to have planning reliability substantially in excess of the industry average PPC of 54%; and
  - to insure that the PPC measurement is on an upward improving trend.
- Regular assessments of the team's use of the Last Planner® are to be made to ensure continued improvement of behaviors, process, discipline, tools.



4 Quality of Work

4.1 Quality Initiative

The goal of the Project is production of defect-free work at the least cost and in the least time possible. Defect detection after the hand-off of work between trades or disciplines is costly both in time and dollars. Inspection is not a value-adding activity. Assuring an understanding of the conditions of satisfaction and completion in accordance with that understanding is essential to establishing proper workflow. To the maximum extent possible, quality should be controlled at the source, where the work is being performed, and by those individuals performing the work.

4.2 Quality Plan

The Designer and Construction Manager, in collaboration with the other Project Team members, shall participate and develop a quality plan that, at a minimum, addresses the following issues:

A. Confirming that Conditions of Satisfaction are clearly communicated to Project participants.
B. Training workers on the harm generated by work failing to satisfy the Conditions of Satisfaction and the benefits of standardized work practices (and their continuing improvement).
C. Developing the use of mockups, first run studies, early completion of standard work units, and similar efforts to physically document acceptable levels of quality.
D. Providing quality checklists (specific, tasked based) for use by workers to self-evaluate quality, establish benchmarks and structure continuous improvement.
E. Design of feedback mechanism for onsite managers and other quality assurance or inspection entities to review early work product and assure completion according to conditions of satisfaction.
F. Integration of quality review and assurance with hand off criteria and the make ready, look ahead plan.
G. Procedures for trades to discuss and assure quality at hand off of work.
H. Procedures for immediately addressing quality failures by the workers originally performing the work to assure minimum cost and maximum learning.
I. Procedures for recognizing outstanding performance and quality according to the conditions of satisfaction.
J. Measurement of quality reliability index to track performance of quality assurance system and record reasons for variance to support continuous improvement.

K. Program for achieving zero punch list items, timely commission and close-out at project completion.
L. Integration with project specific quality deliverables.
M. Development of a responsibility matrix for the quality assurance system.

5 BUDGET AND COST MODELING

The cost control to be performed on the Project shall be "target value design" and consider the following holistic costs: capital (first), energy (consumption), maintenance, replacement and consider salvage value, embodied energy value (carbon) and occupant productivity/ health. The project team will use a target value design process throughout the design process to maximize customer value within project constraints.

5.1 Target Value Design

The Owner anticipates that Construction Manager and the Trade Specialists will provide Target Value Design support services throughout development of the design. Support includes costing both first installed costs, operating costs, embodied energy and environmental costs. Depending on the stage of the document development, the scope and nature of this ongoing effort may change. The listings of the specific estimates below are specific "roll up estimates" or "gate estimates" to provide the Owner the opportunity to confirm that the Work, at those milestones, is proceeding within the approved budget parameters. Those estimates shall be the by-product of the ongoing target value pricing process and are not intended to be performed by advancing the documents to a certain stage of development and then requesting that the Construction Manager and the Trade Specialists provide pricing information. As noted, Construction Manager and the Trade Specialists will be expected to provide ongoing cost information and estimating of the Work, systems being considered, details as they are developed, and other cost exercises that the Project Team deems advisable.

5.2 Target Value Design Process

Target Value Design is intended to make explicit that value, cost, schedule and constructability are basic components of the design criteria. The Project Team shall develop a procedure for the use of Target Value Design principles throughout the design process. At a minimum, these procedures should address the following:

A. Method to establish initial target costs for major components and systems.
B. Method for determining other value elements of Target Value Design.
C. Agree on schedule for selection of Trade Contractors (during concept design).
D. Method for forming and meeting structure for cross functional teams (clusters) of designers and builders for major components and systems of the site and structures.
E. Method for aligning all Project participants behind the cardinal rule of Target Value Design: the Construction Target Budget shall never be exceeded without express written approval of Owner.
F. Method to assure cost analysis and reporting procedures within the cross functional teams (clusters) for monitoring estimated costs against target costs.
G. Creation of a Target Value team comprised of the cross functional/cluster leaders to meet regularly and frequently with the responsibility of providing direction for dealing with Target Value Design tradeoffs and opportunities, including function/cost trade-offs and be the authority to direct value engineering and adjustments of the component/system costs up or down to maintain Construction Target Budget.

6 INTEGRATED STRATEGIES

6.1 Collocation

Collocation is intended to create collaborative work environment by reducing inefficiencies in communication. Creating an atmosphere with mechanisms to facilitate the adequate sharing of information among Project Team members is essential for meaningful collaboration. Once the team is formed, it is important to create a team atmosphere where collaboration and open communication can flourish. Locating the team in a shared or common office may facilitate open communication and cooperation, and regular meetings and video conferences may be useful when collocation is impractical. Regardless of the methods employed, it is necessary to establish a team where participants are willing and able to work together effectively and to provide the Project Team with tools and circumstances that facilitate collaborative performance. Project Team's roles and responsibilities are comprehensive than traditional processes. Role definitions are given below to understand the scope of responsibilities through the collaborative process.

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Collocation streamlines the flow of information among the Project Team. During the Design Development phase, the Construction Manager's team should work closely with the Designer's team within a shared office space. Collocation gives the Construction Manager an opportunity to provide constructability feedback, design review services, material selection recommendations and schedule sequencing suggestions. Permanent desks and workstations should be maintained onsite at the Project location for members from the Designer, Construction Manager and Owner firms to provide a collaborative space for design coordination in real-time. To plan collocation requirements onsite, a phase matrix, similar to the example provided in Table 6-1, should be generated collaboratively with the Project Team prior to the start of construction to identify deliverables, information needs, required team capabilities and the expected collocated team.

6-1: Example of collocation phase matrix to be created by Project Team

PHASE	DELIVERABLE	NEEDS	TEAM CAPABILITIES	CO-LOCATED TEAM
Design Development (DD)	Design Development Package	Initial design scheme of the Project scope, including relationships between building components	• Evaluate and select major systems/components • Monitor design and construction budget • Verify with end-user	• System engineers • Architect • GC/CM
Construction Documents (CD)	Construction Document Package	Coordinated description of all building systems	• Detailed design documents • Coordination • Prefabrication planning • Long lead procurement	• MEP design engineers • System engineers • Architect • GC/CM

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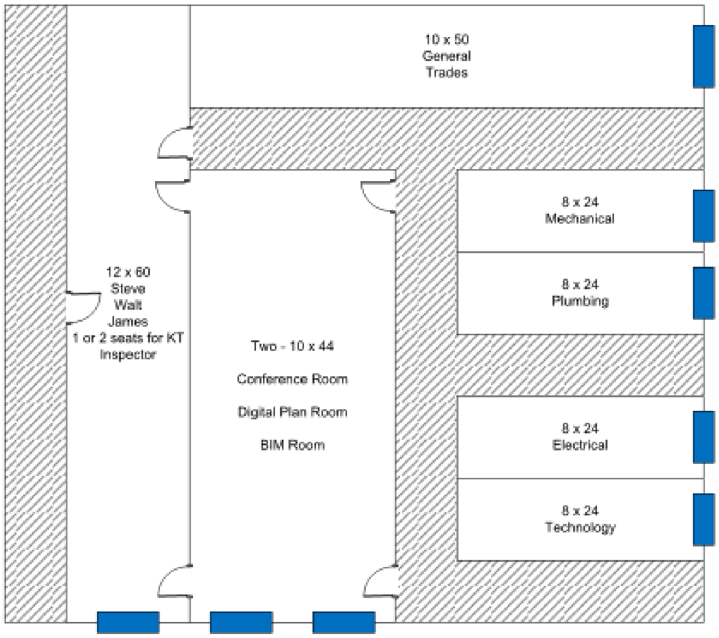
After award of the construction trade contracts the integrated project team will initiate the project with a project kick-off/ collaboration meeting.

Project Kick-off/ Collaboration Meeting Agenda:

- Int⁺oŰkctionABCnŰBD⁺oFctBOvF⁺vFwB
- TFCmBBkďŰngBCnŰBAlgnmFntB(D⁺oFctBVClkFA/BGovF⁺nCnF)B
- D⁺oF AABCnŰBD⁺oF Űk⁺FAB
    - D⁺oFctBnfo⁺mCtonBFlowB
        - BkďŰngBnfo⁺mCtonB oŰFlngB
        - !ggtClB' o⁺#flowAB(Ak$mgtClA/B%FlA)B
- &chFŰklFBB
    - OvF⁺vFwBCnŰBvClŰCtFBcont⁺CctBŰk⁺CtonB(mďFAtonFA/B(' CAFBŰk⁺CtonA)B
    - DkllB(lCnngBoBŰFvFlo(B) BwFF#Boo#C' FCŰBCnŰBwFF#l*BcyclFB

Before start of construction the General Trades contractor will install a collaborative office complex to collocate the Owner, Architect, CM and Trade Contractors. The following is an example of how this complex would look.



6.2 Value Analysis Strategy

Throughout the design phases, and with particular attention during the Concept and Basis of Design phases, Construction Manager and the Trade Contractors shall, on an ongoing basis, pursue opportunities to create additional value by identifying options to reduce capital or life cycle cost, improve constructability and functionality, or provide operational flexibility, while satisfying the Owner's programmatic needs. In order to avoid waste associated with re-drawing aspects of the work, the emphasis on value analysis and the opportunity for set-based design (carrying multiple design options forward and deferring decisions until the last responsible moment) must be emphasized early in the design process. In order for these efforts to be effective, the Project must gain the early input of Trade Contractors who possess information essential to the value analysis process. The Project Team should focus on developing strategies to utilize value analysis as part of its Target Value Design efforts.

6.3 Tools and Technology

Several tools and technologies are suggested to improve the visibility of work processes. These tools can provide a transparent medium to share information, knowledge and also achieve deeper collaboration. BIM (Building Information Model), A3 Reports, Choosing by Advantages (CBA), Last Planner System, Process Mapping and Value Stream Mapping are some of the tools recommended to the Project Team to improve the quality of collaboration.

a) ***BIM*** is used by Designers and Construction Managers and offers enormous potential to eliminate waste from building design and construction. Designers and builders are currently each using BIM to optimize their own individual processes – the production of construction documents for architects and engineers and coordination and fabrication documents for the Construction Manager. The real promise for BIM, however, lies in using BIM as a collaborative tool without the limitations imposed by the paper-based deliverables prescribed by conventional contracts.

b) ***A3 Reports*** are frequently used to improve the problem solving skills of the project team members by encouraging collaboration, and concisely documenting decisions, plans and results. The steps of creating a typical A3 report include: identifying a problem, understanding the current condition, determining the root cause, developing a target condition, implementation plan, and follow-up plan. These steps are all written and drawn out on a single piece of 11” x 17” paper. The problem-solver records the results of investigation and planning in a concise, two-page document that facilitates knowledge sharing and collaboration.

c) ***Choosing by Advantage (CBA)*** is a systematic method of decision-making based on the importance of advantages; not pros and cons, advantages and disadvantages, goals and roles. CBA includes a wide variety of decision-making tools, techniques, and methods that are unified by just one set of definitions, principles and model. It is a system used to choose between different alternatives for specific design issues, green attributes and BIM tools.

d) ***Process Mapping*** addresses all activities involved in defining exactly what an organization does; who is responsible; how a process should be completed; and how the success of a business process can be determined. A process map is one of the most important visual displays of “who does what” and “when” activities are accomplished. It helps identify the greatest opportunity for improvement. A process map also improves the visibility or transparency of a process. Process maps generated by the Project Team should be presented using the Business Process Model and Notation (BPMN) standard or another approved modeling notation.

e) ***Value Stream Mapping*** tool is used to analyze the flow of materials and information required to bring a product or trade to the final project. A value stream map is used to eliminate non-value adding activities and provide continuous improvement to the various trades.

6.4 Value Analysis Proposals

Construction Manager and the Trade Contractors shall be encouraged to bring forward alternative systems, means, methods, configurations, finishes, equipment and the like that satisfy the general design criteria of the Project, but which result in savings of time or money in constructing or operating and maintaining the Project, or increasing quality, constructability, or other measures of value and are cost neutral. Each proposal shall examine the proposed change, identify all aspects of the Project directly or indirectly affected by the change, specify the cost or time savings to be achieved if the proposal is accepted, and detail any anticipated effect on the Project's service life, economy of operation, ease of maintenance, appearance, design or safety standards. The Project Team shall initially review and consider whether to incorporate a proposal in the Project. For proposals that are adopted, the responsible designers shall ascertain design feasibility, satisfaction of the design concept, compatibility and compliance with Applicable Laws, and professional standards of care.

7 PERFORMANCE MEASUREMENT

7.1 Goal

The Owner believes that, by utilizing a more integrated delivery approach, wasted cost and time will be eliminated from the design and construction process and the quality of the final product will be increased. To encourage and promote a more integrated delivery, the Owner will establish a measurement process, intended to foster collaboration and cooperation among the Project Team members, incentivize Project Team performance and improve the overall quality of the Project. The process measures team successes and the meeting of team goals, but is not intended to acknowledge individual performance when team goals have not been met as a whole.

7.2 Review Periods

The measurement process is distributed over five (5) discrete review periods, between the date of contract award and project turnover. The date range, duration of each review period is summarized in Table 7-1.

7-1: Summary of performance incentive review periods

Review Period	Dates of Period
1	Design Development
2	Prime Contractor Procurement
3	Demo/ Structure Completion
4	Enclosure Completion
5	Final Completion/ Close-out

7.3 Evaluation Categories

The project team's performance will be evaluated within each review period, based on the following five categories: safety, schedule performance, cost performance, quality of work and project team. The relative weighting of each criterion and the distribution within each review period is summarized in Table 7-2.

7-2: Summary of performance categories and weightings by review period

Criteria	Overall Criteria Weighting	Review Period				
		1	2	3	4	5
Safety	20%	*20%*	*20%*	*20%*	*20%*	*20%*
Schedule Performance	20%	*20%*	*20%*	*20%*	*20%*	*20%*
Cost Performance	20%	*20%*	*20%*	*20%*	*20%*	*20%*
Quality of Work	20%	*20%*	*20%*	*20%*	*20%*	*20%*
Project Team	20%	*20%*	*20%*	*20%*	*20%*	*20%*
	100%					

7.4 Detailed Evaluation Criteria

Within each evaluation criteria category are several detailed requirements for the project team, including specific prerequisites which must be achieved. These should be project-specific and agreed upon by the Project Team as reasonable Project goals.

1	Safety	Weighting
P1.1	*Prerequisite 1:OSHA RIR and LTC less than national average for project-to-date work-hours*	*Prerequisite*
P1.2	*Prerequisite 2:Updated, written site-specific safety plan and weekly project orientation plan*	*Prerequisite*
1.1	"Safety First" project culture (subjective, evaluated by Owner)	45%
1.2	Zero OSHA lost-time incidents	45%
1.3	Zero bystander safety incidents	10%

2	Schedule Performance	Weighting
P2.1	*Prerequisite 1: Updated phase planning, look-ahead schedules, milestone schedules and weekly work plan*	*Prerequisite*
2.1a	Timely communication by project team – percentage of RFIs completed within 3 days	30%
2.1b	Timely communication by project team – percentage of submittals A/AAN within two weeks	30%

2.2	Percentage of milestone design deliverable and construction dates met	40%

3	**Cost Performance**	**Weighting**
P3.1	*Prerequisite 1: Updated budget, cost reports, change order logs and buyout reports.*	*Prerequisite*
3.1	Change order management and tracking (over 90% of change orders resolved within 30 days of identification of change)	20%
3.2	Percent change between buyout and pre-bid estimate	20%
3.3	Actual Project costs below target cost (trends at specific milestones)	60%

4	**Quality of Work**	**Weighting**
P4.1	*Prerequisite 1: Submitted and updated appropriate quality assurance plan; reviewed and approved by the Project Team.*	*Prerequisite*
4.1	Building system performance exceeds Project energy goals.	60%
4.2	Zero field installation conflicts.	20%
4.3	Percentage of QC log items resolved within 30 days	20%

5	**Project Team**	**Weighting**
P5.1	*Prerequisite 1: Documented compliance with Collaboration Addendum.*	*Prerequisite*
5.1	Collocation used to create collaborative work environment, as defined in the responsibility matrix planned by the Project Team	25%
5.2	Perform 360° evaluations of Project Team members and identify steps to improve collaboration	75%

8 MISCELLANEOUS

8.1 This Addendum represents the objectives of the parties with respect to the execution of their respective contracts with their mutual client, the Owner of the Project. It is the desire and intention of the parties to cooperate, collaborate and coordinate in the performance of their separate contractual duties and responsibilities for the mutual benefit of the Project. The stated objectives of this Addendum notwithstanding, nothing contained herein shall be construed to create a separate contractual relationship between any of the parties, to render any party to this Addendum responsible for the contractual obligations of any other party or to make any party a third party beneficiary of any other party's contract with the Owner.

8.2 This Addendum shall not make any Party responsible for the errors, omissions, or breaches of the separate agreement of any other Party.

8.3 Nothing in this Addendum shall be deemed to give Construction Manager or Trade Contractors any responsibility for the design, or to give the Architect or Subconsultants any responsibility for ways, means, methods, techniques or sequences of construction or for safety programs or precautions in connection with the Work.

8.4 Except where otherwise expressly provided in this Addendum, in the event of a conflict between this Addendum or a separate agreement, the separate agreement shall govern.

8.5 .

8.6 Architect's and Construction Manager's obligations under this Addendum are subject at all times to the condition precedent that Architect and Construction Manager have an [active and ongoing] separate agreement with Owner.

Appendix B: BIM Contract Addendum and BIM Project Execution Plan, Pennsylvania State University

PENN STATE OFFICE OF PHYSICAL PLANT BUILDING INFORMATION MODELING (BIM) CONTRACT ADDENDUM

Version 2.0
09.20.2012

The purpose of this addendum is to define the scope of Building Information Modeling (BIM) for facilities designed and constructed for The Pennsylvania State University. This document is to be used in conjunction with the OPP BIM Project Execution Plan Template[1], the OPP BIM Standards and Guidelines[1] document, Asset Attribute Requirements[1] and referenced by FORM OF AGREEMENT 1-P, 1-S and 1-C, 1-CM(GMP, SP, P). The content of this addendum may be modified by the OPP project leader based with support from the OPP BIM team on project specific constraints. Please read the document entirely and contact Colleen Kasprzak by phone at 814.865.7269 or by email at cmk264@psu.edu, if you should have any questions.

This addendum applies to all projects exceeding a Total Project Cost of $5 million new construction, substantial renovation, or as directed by the OPP project leader.

DEFINITION OF TERMS

PSU: The Pennsylvania State University (Owner)

OPP: The Office of Physical Plant at PSU, interchangeable with PSU

Professional: Designer, Architect, Engineer or Consultant

Construction Manager (CM): Construction Manager (CM) Agent or At-Risk; or General Contractor (GC)

Contractor: Contractor responsible for performing work, contracted directly with the owner. May have additional **subcontractors**. Contractor will be responsible for construction of and processing of building information based on scope of work.

Project Team: Professionals, CM, Contractor, Owner, and other stakeholders

Project Leader: Penn State Project Manager (PM) or Project Coordinator (PC)

As-Built Model Deliverable: Model(s) based on Means and Methods Model(s) and installed conditions

Building Information Modeling (BIM): A process focused on the development, use and transfer of facility attribute data of a building project to improve the design, construction and operations of a project in order to achieve project specific goals

BIM Project Execution Plan: a plan that defines how BIM will be implemented throughout the project lifecycle. (Also referred to as BIM PxP)

CAD Deliverable: submitted CAD drawings (e.g. plans, elevations, sections, schedules, details, etc.) in the form of shop drawings, design deliverables, and as-built drawings

Design Intent Model: Model(s) based on criteria that is important to the translation of the facility's design

Facility Attribute Data: Associated intelligent attribute data (e.g. manufacturer, model, warranty information, etc.)

Level of Development (LOD): Level of completeness to which a model element is developed at the end of each design and construction phase

Means and Methods Model: Model(s) based on criteria that is important to the translation of the facility's construction

Model Element: Portion of the model(s) representing a component, system, or assembly within a building or site

[1] Latest version available for download at www.opp.psu.edu. Please contact Colleen Kasprzak by phone at 814.865.7269 or by email at cmk264@psu.edu, if you should have any questions.

Model Element Author: Responsible party for developing the BIM content of a specific Model Element to the LOD required for a particular phase of the Project

Project Lifecycle: from conception to demolition including four distinctive phases (Planning, Design, Construction, and Operations)

Record Model Deliverable: Model(s) based on Design Intent Model(s) and installed conditions

ARTICLE 1: PROJECT BIM REQUIREMENTS

1.1. BIM Project Execution Plan. The Project Team shall develop a BIM Project Execution Plan (BIM Plan) documenting the collaborative process in which BIM will be implemented throughout the lifecycle of the project. Refer to Article 2.0 of this document for requirements for the BIM Plan.

1.2. Model Element Authoring. Develop all designs using Building Information Modeling (BIM) and Computer Aided Design (CAD) software. See Article 4.3 for model reliance information.

1.2.1. Design Intent Model. The Professional shall develop a Design Intent Model that includes all accurate and relevant geometry and facility information required to design the facility. This model will be transferred to the Construction team for the creation of the Means and Methods Model. Professional will update the Design Intent Model with all design revisions at agreed upon intervals during the Construction phase.

1.2.2. Means and Methods Model. The Contractor shall develop a Means and Methods Model that includes all accurate and relevant geometry and facility information required to construct the facility. Contractor will update Means and Methods Model with all revisions at agreed upon intervals during the Construction phase. Please reference Section K- Attachment 3 Facility Attribute List. Each contractor is responsible for entering/ verifying their own systems. Information entered into the Facility Attribute list needs to match approved submittals and in the event of major equipment/ attribute changes, RFI or re-submittal of product data is required…Prior to or at the time of installation, this information should be timely entered into the Facility Attribute List.

1.2.3. As-built Model. A Project Team member, preferably the Contractor, will validate the Means and Methods Model to produce a field accurate As-built Model to be delivered to PSU at project turnover.

1.2.4. Record Model. A Project Team member, preferably the Professional, will validate and revise the Design Intent Model to produce a field accurate Record Model to be delivered to PSU at project turnover.

1.3. Model Responsibility. It shall be understood that there may be an information gap between what is required for the final BIM deliverables to the Owner and what is required for each team member to perform their required and/or recommended BIM Use. It is responsibility of the individual member of the Project Team to provide that information. If developed, all information shall be made available to the entire Project Team.

1.4. BIM Model and Facility Attribute Data. Professionals shall use BIM application(s) and software(s) to develop project designs. Professionals shall use the Design Intent Model to produce accurate Construction Documents. All submitted BIM Models and associated Facility Attribute Data shall be fully compatible with the latest version of Autodesk Revit at the time of Design.

1.4.1. BIM Model Updates. The Project Team will update the Model with any revisions as required to complete the work, or at a minimum, at each Design Phase Submittal. The Model shall remain current and represent design intent.

1.5. Drawing Requirements. Deliver Construction Document drawings per requirements with any revisions as specified in the OPP Design and Construction Standard. Specification of a CAD file format for these Drawings does not limit which BIM application(s) or software(s) may be used for project development and execution.

1.5.1. Drawing Deliverables. Submitted drawings (e.g. plans, elevations sections, schedules, details, etc.) shall be derived (commonly known as extractions, views or sheets) and maintained from the submitted Model and Facility Attribute Data.

1.5.2. Deliverable Requirements. BIM deliverables shall conform to the requirements of Article 3.0 below.

1.6. Owner Requirements

1.6.1. Model Content. The Model and Facility Attribute Data shall include, at a minimum, the requirements of Section 11.0 <u>Model and Database Structure</u> in the BIM Plan. Further content may be specified in the BIM Information Exchange Worksheet (Section 6.2: Developing Information Exchanges of the BIM Plan) which defines the exchange of information between each project phase for each project team member and the Facility Asset Attribute List (Section 7.0/ Attachment 3 Asset Attribute Information (of the BIM Plan).

1.6.2. Model Granularity. Models vary in level of detail for individual elements with a model, but at a minimum must include enough detail to establish design intent, perform BIM Uses specified in Section 4.2 Project BIM Uses of the BIM Plan, coordinate and detect clashes in the model prior to the creation of Construction Documents, create Construction Documents, and meet the deliverable requirements of the BIM Plan. Submitted models shall have a scale of 1:1.

1.6.3. Facility Attribute Data. Develop Facility Attribute Data consisting of intelligent elements for the Model (e.g. doors, air handlers, electrical panels, etc.). This Facility Attribute Data shall include all material definitions and attributes that are necessary for the Project design, construction, and operations. Minimum Facility Attribute Data requirements are located in Section 7.0/ Attachment 3 Asset Attribute Information of the BIM Plan.

1.7. Quality Control. Implement quality control (QC) parameters for the Model, including procedures described in Section 11.3: Quality Control Procedures of the BIM Plan. As a minimum provide the following:

1.7.1. Model Standards Checks. QC validation used to ensure that the Model(s) have no undefined, incorrectly defined, or duplicated elements. Report non-compliant elements and corrective action plan to correct non-compliance elements. Provide OPP with detailed justification and request OPP acceptance for any non-compliant element which the Project Team proposes to remain in the Model(s).

1.7.2. CAD Standards Check. QC checking performed to ensure that the fonts, dimensions, line styles, levels, and other Construction Document formatting issues are followed per the OPP Design and Construction Standards.

1.7.3. Model Commissioning. QC validation to ensure that the model and database is compliant with the defined quality control procedure for component level of detail and stakeholder information.

1.7.4. Other Parameters. Develop such other QC parameters as Professional, CM, and Contractors deem appropriate for the Project and provide to the OPP for concurrence.

1.7.5. Over-The-Shoulder Quality Control Review. Periodic QC meetings shall include reviews of the implementation and use of the model, including but not limited to, interference management, design change tracking information, and coordination validation as agreed upon in Section 9: Quality Control Procedures of the BIM Plan.

1.8. Project BIM Uses. Section 4.2: Project BIM Uses of the BIM Plan indicates the minimum BIM Use requirements for each project phase.

2.0 ARTICLE 2: BIM PROJECT EXECUTION PLANNING

2.1. The BIM Plan will be developed by the Project Team members documenting the collaborative process in which BIM will be implemented throughout the lifecycle of the project. The Professional shall lead the development of the BIM Plan during the design phase and the CM shall lead development during the construction phase.

2.1.1. An initial BIM Plan shall be developed by both the Professional and CM detailing the requirements identified in this Addendum and the OPP BIM Plan Template. It shall be submitted for approval by the PSU prior to contract execution.

2.1.2. A collaborative BIM Plan shall be developed with the Contractor and CM prior to completion of the schematic design phase. In the event that a Contractor is not procured for preconstruction services, the Professional Team and Owner shall develop the collaborative BIM Plan and revisited when the Contractor is procured.

2.1.3. The BIM Plan shall be revisited with the entire project team prior to Construction and submitted to the OPP for final approval. The BIM Plan shall be reviewed with specialty contractors prior to their contract execution. Any revisions to the BIM Plan must be submitted to the OPP for final approval

2.1.4. Payment may be held at each development phase until the BIM Plan is approved. Suggested review milestones can be found in Section 2.5: Project Milestones of the BIM Plan.

2.2. In developing the BIM Plan, both the Professional and Contractor will utilize the latest version of the OPP BIM Project Execution Plan Template (BIM Template), which identifies the minimal BIM Requirements to develop an acceptable BIM Plan.

2.3. Model Development Process. The process in which project team members create and share facility information for downstream stakeholders to produce intermediate and final deliverables. An agreed upon model development process must be reviewed by the project team and approved by OPP. An example of this process can be found in Section 1.2 Record Model & As-built Model Development Process of the BIM Plan.

2.4. Within ten (10) days after the acceptance of the BIM Plan, the Project Team shall conduct review and demonstration to verify the functionality of the Model technology workflow and processes set forth in the BIM Plan. If modifications are required, the Project Team shall complete the modifications and resubmit the BIM Plan and perform a subsequent demonstration for OPP acceptance. OPP may also withhold payment for Design and Construction for unacceptable performance in executing the accepted BIM Plan.

2.5. Reference. For additional information regarding the OPP BIM requirements, please reference the OPP BIM Standards and Guidelines.

3.0 ARTICLE 3: PROJECT DELIVERABLE REQUIREMENTS

3.1. Provide deliverables in compliance with the BIM Plan Deliverables at stages described in Section 2.5: Project Milestones of the BIM Plan.

3.1.1. At each stage, provide a written report confirming that consistency checks as identified in Article 1.7 have been completed. This report shall be discussed as part of the review process and shall address cross-discipline interferences, if any.

3.1.2. At each stage, provide OPP with the following (as detailed in Section 12: Project Deliverables of the BIM Plan):

3.1.2.1. BIM Project Execution Plan.

3.1.2.2. Design Intent Model(s)

3.1.2.3. Two dimensional drawing deliverables printed directly from the model in PDF format. Documents to be stamped and signed in traditional practice to comply with the OPP Design and Construction Standard and local permitting requests.

3.1.2.4. Means and Methods Model(s) per Discipline

3.1.2.5. A three dimensional interactive review format of the Model in the latest version of Autodesk Navisworks, Adobe 3D PDF or other format as per the BIM Plan requirements. The file format for reviews can change between submittals.

3.1.2.6. Construction Submittals. All Construction Submittals, Request For Information (RFI), and Change Order Requests (COR) should make use of the model for clear interpretations.

3.1.2.7. Record Model(s)

3.1.2.8. As-built Model(s)

3.1.2.9. A report generated from the Model of all assets and attributes (K.3- Facility Attribute List.xls)

3.1.2.10. A report verifying the Model compliance with PSU Facility Attribute Database

3.1.2.11. A report verifying the accuracy of the delivered model elements and asset attributes

3.1.2.12. An Interference Check Report

3.1.2.13. A list of all submitted files. The list should include a description, directory, and file name for each file submitted. Identify files that have been produced from the submitted Model and Facility Attribute Data.

3.1.2.14. The BIM Plan will define additional intermediate deliverables for the project

3.2. OPP shall confirm acceptability of all project deliverables.

4.0 ARTICLE 4: OWNERSHIP, RIGHTS, AND LIABILITIES IN DATA

4.1. Ownership. The BIM Model is an instrument of service and is considered to be a component of Design and Construction Documents governed by Article 7 of the Owner/Professional AGREEMENT (Form 1-P), Article 1 of the Owner/Contractor Agreement (Form 1-C), and Article 14.3 of General Conditions of the Contract (Form CM-GMP-GC) without exception. In addition, each Model Element Author (MEA) contributing to the BIM model(s) and database agrees to provide all project stakeholders and Penn State (Owner) a non-revocable, exclusive license to utilize any and all intellectual property provided by each MEA contained within this BIM for the sole purpose of completing the design, construction and other uses as stipulated and/or implied by the executed Owner/Professional Agreement and Owner/Contractor Agreement for this project.

4.1.1. Submitted Model(s), drawings, and all embedded asset attribute information shall be validated by Contractor may be used at the discretion of the OPP throughout the construction and lifetime of the facility.

4.2. Liability. Nothing in this Addendum shall relieve the Professional from their obligation, nor diminish the role of the Professional as responsible for and in charge of the design of the project and respective model(s).

4.2.1. No parties involved in creating in model shall be responsible for costs, expenses, liabilities, or damages which may result from the use of the model beyond the uses described in the BIM Plan.

4.3. Reliance on Model Elements. The BIM Model(s) produced by the project stakeholders associated with the Professional will serve as the basis of design and is considered the Design Intent Model. The model prepared by the Professional will be used by the Contractor to prepare a Means and Methods Model. This Right of Reliance pertains to all models and applications associated.

4.3.1. The Construction Team may rely on the accuracy of the model(s) prepared by the Professional in accordance with the traditional Standard of Care provisions that apply and govern the design and construction of comparable building in two dimensional design formats and methods.

4.3.2. Conversely, the Professional may rely on the accuracy of the model(s) prepared by the Construction Team in accordance with traditional Standard of Care provisions that apply and govern the preparation of shop drawings, fabrication drawings, sequencing and other instruments used to convey the means and methods under the control of the Contractor, subcontractors, consultants and other agents working on this project.

4.3.3. As mutually agreed by all parties, including Professional, Contractor, and Owner, nothing shall be construed by the content and/or preparation of the associated model(s) as a warranty or guarantee of accuracy and/or completeness by the Professional. Standard and traditional procedures for design, documentation, means and methods, shop drawing submittals, verification by the contractor, requests for information, etc. shall apply to the design, construction and construction administration of the project.

4.3.4. The construction manager, contractors and subcontractors shall be solely responsible for means and methods and the execution of the Design Intent Model through the execution, preparation and management of delegated design, the Means and Method Model(s), fabrication, installation, and construction.

5.0 ARTICLE 5: BIM SCHEDULE OF VALUES

5.1. The Professional(s) and Contractor(s) shall provide any cost incurred to comply with the OPP BIM Addendum. All costs are included in the base contract prices. The Professional(s), CM, and Contractor(s)/ Subcontractor(s) are responsible for developing a Schedule of Values to perform additional BIM services. The Schedule of Values will be submitted for approval to PSU prior to contract execution.

5.2. Requiring BIM implementation on a project should not result in an increase of total project cost; however, PSU realizes BIM implementation may result in a shift of fee structure and an increased cost of model, data, and document management and maintenance. PSU reviews BIM related items for the project prior to the issuance of the RFP and BID Document for a clear understanding of the potential cost impact that may be associated with unique modeling and/or facility data requirements.

5.3. PSU is aware that there is an earlier expenditure of design production and design/construction coordination hours when using BIM processes and the OPP BIM Addendum provides a payment schedule specific to projects implementing BIM. The cost for purchasing BIM authoring software and training will not be compensated by PSU as reimbursable to the project requiring BIM implementation. Additional service fees may be considered for owner requested further model development and enhancement during the construction phase, but not for as-built or post construction documentation requirements, as detailed in the OPP BIM Addendum.

5.4. Requirements for BIM management and participation will be described in the project specific RFP and incorporated into the corresponding fee proposals. The modeling requirements for the project will be described within the project BIM Plan and Bid Documents and will be included in the bid. All costs of this addendum must be included in your contract.

5.5. The purpose of the BIM Addendum is to define the scope of Building Information Modeling (BIM) for projects designed and constructed for The Pennsylvania State University. This document is to be used in conjunction with the OPP BIM Project Execution Plan Template, the OPP Owner BIM Requirements, and FORM OF AGREEMENT 1-P, 1-C, and 1-CM-GMP. The content of the addendum is modifiable based on project specific constraints.

5.6. It is the responsibility of all project stakeholders to have or obtain, at their cost, the trained personnel, hardware, and software needed to successfully implement BIM for the project. Equipment used by the Contractor/ Subcontractor during the on-site coordination meetings must meet requirements of the software being implemented so as not to cause delays in modeling, redrawing, and/or duplication of work. All technical disciplines shall be responsible for their data integration and data reliability of their work and coordinated BIM Model(s) and facility data.

6.0 ARTICLE 6: BIM COORDINATION REQUIREMENTS

6.1. Contractor/ Subcontractor shall participate in a BIM coordination process as defined and led by CM. This process will be a collaborative effort with the Professional, CM, Contractors and its participating subcontractors, which includes but is not limited to architecture, as well as the Mechanical, Plumbing, Electrical, Telecommunications, Fire Protection and Structural trades. Accordingly, Contractors/ Subcontractor shall be responsible for preparing a three-dimensional (“3D”) representation in electronic format of the building elements that comprise Contractors/ Subcontractor’s work (a “Model”). In the event

Contractor is providing design-build services through a separate contract with a design professional, the Subcontractor agrees to abide by the requirements contained in any BIM attachment to the contract between the Contractor and its design professional and any Project specific BIM implementation plan governing the use of BIM so long as consistent with the requirements of this Addendum. In addition, the coordination process shall be in accordance with the overall Project Schedule and Contract Documents, and shall be subject to the following conditions and requirements:

6.1.1. All BIM and 2D CAD file data issued to the Contractors/ Subcontractor by either the Professional and / or Contractor shall be used for spatial coordination. Unless otherwise specified by the Prime Contract or Design Agreements, these electronic files are not to be considered Contract Documents and in no way are they a substitution for them. The information provided is to facilitate shop drawing development and spatial coordination. All information contained in the electronic files must be verified by using the Contract Documents and, to the extent possible, observations by Contractors/ Subcontractor of existing conditions or prior construction work put in place.

6.1.2. The shop drawings for Contractor/ Subcontractor's work must be created and maintained in a 3D software program that is compatible with Navisworks software for reference by Contractor and related trades during the MEP coordination process and during field installation. In addition, the Subcontractor is required to own a license to Navisworks software in order to facilitate its participation in the Project's modeling process, and must provide its 3D files to CM in ".nwc" format to the extent doing so is feasible. Contractors/ Subcontractor represents that the dimensions contained in its Model are accurate. Provided, however, that with respect to any dimensions that cannot be field verified at the time transmitted to CM because of the current progress of construction, it is understood that the accuracy of certain dimensions provided by Contractors/ Subcontractor may be dependent upon the accuracy of the dimensions contained in the Contract Documents applicable to or that interface with Contractors/ Subcontractor's work.

6.1.3. As part of the MEP coordination process and prior to each MEP coordination review session, Contractors/ Subcontractor shall create and make available to CM, other Contractors and related subcontractors the Model relating to Contractors/ Subcontractor's work. Contractors will supply a sequence of activities and a schedule for electronic deliverable exchanges prior to the commencement of MEP coordination activities. Contractors/ Subcontractor will revise and maintain its Model in accordance with this schedule.

6.1.4. Contractors/ Subcontractor's Model must be revised throughout the MEP coordination process and later during field installation to reflect changes and as-built conditions. In addition to the requirements above, Contractors/ Subcontractor's Model (electronic deliverable) shall be made available to CM and other Contractors whenever updated or revised by Contractor/ Subcontractor, or when requested by CM.

6.1.5. All files will be transferred between Contractors/ Subcontractor and CM via a collaborative project management system hosted by CM.

6.1.6. Electronic Model files will be transferred to CM in a format that is compatible with Navisworks software. Any other file formats must be approved by CM prior to the start of the MEP coordination process.

6.1.7. The Model files transferred to CM must contain objects modeled as solids (not wire frames or lines).

6.1.8. Contractors/ Subcontractor shall use agreed upon file naming structures, areas/zones, layers, system and object coloring, origin point(s) and title blocks as they relate to both 2D and 3D electronic files when transferring files to CM. These items will be agreed upon prior to the commencement of the MEP coordination process.

6.1.9. Shop drawing and submittal data shall also be made available to CM in a 2D drawing or compatible vector file format as directed by CM. When requested, these files will be transferred to CM on a mutually agreed upon date.

6.2. Contractor/ Subcontractor warrants that it is the owner of all copyrights in its Model or that Contractor/ Subcontractor is licensed or otherwise authorized by the holders of any such copyrights to provide CM and/

or Owner with the contents of the Model. Subject to any ownership rights in the Model that are required by the Prime Contract to be given to the Owner, Contractors/ Subcontractor shall retain ownership of any copyrights in its Model. Contractors/ Subcontractor hereby grants to CM and Owner a limited royalty free non-exclusive license to reproduce, distribute, display or otherwise use Contractor/ Subcontractor's Model for purposes of conducting training, constructing, completing, renovating, expanding, modifying, operating or maintaining the Project.

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ELECTRONIC FILE TRANSFER RECORD

TO
Name
[Title]
[Company]
[Address Line 1]
[Address Line 2]
[City State ZIP]
V [Telephone]
F [Fax]

DATE [Date]
PROJECT NUMBER **[KT Project Number]**
PROJECT NAME **[KT Project Name]**

The enclosed electronic files are provided for your convenience and use in the preparation of shop drawings, subject to the following conditions:

1. **These electronic files are not contract documents as that term is used in the Owner-Architect agreement for the above project. No representation is made to the accuracy or completeness of these files, and differences may exist between these files and corresponding hard-copy contract documents. In the event of a discrepancy, the signed or sealed hard copy construction contract documents shall govern.**
2. **The use or re-use of these electronic files by you or by others will be at your sole risk and without liability to KieranTimberlake (KT). You shall indemnify and hold KT, its clients (including Penn State), consultants and employees harmless against all damages, liabilities, losses or expenses arising out of or relating to your use of the electronic files.**
3. **By your use of these electronic files, you are not relieved of your duty to fully comply with the construction documents, including and without limitation, the need to check, confirm and coordinate all dimensions and details, take field measurements, verify field conditions and coordinate your work with that of other contractors for the project.**
4. **KT takes all reasonable precautions to ensure that electronic data stored on our computer systems are free from corruption and viruses. However, we will not accept claims for loss or damage arising from the copying, loading or other using of this data by other parties. We recommend that you advise users of the data to check for corruption and/or viruses.**
5. **If during the course of this project you transfer these electronic files to a third party, you shall obtain their consent to these terms and provide KT with an executed copy by the third party of this file transfer record.**

I have read the above and agree to abide by all the terms and conditions set forth therein. I furthermore have the authority to execute this agreement on behalf of [insert recipient company name].

______________________________ ______________
Name **Date**

____
Position

FROM [sender's name]

COPY TO [copy recipients, if any]

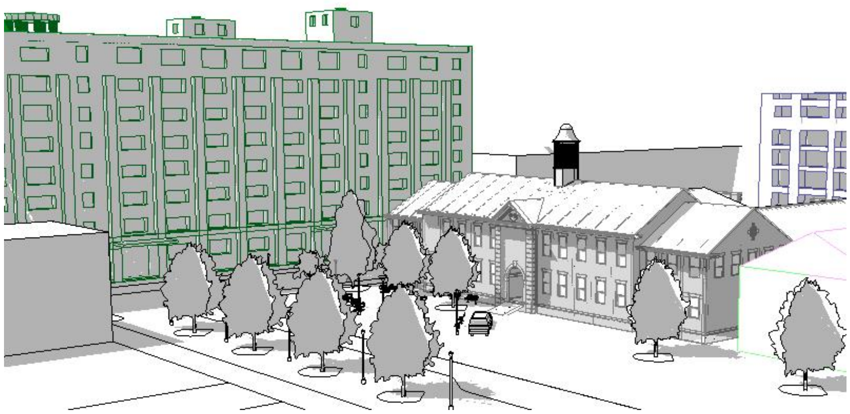
[Identify Electronic files being transferred by file name and date. Make sure that date of electronic drawing issue by KT is indicated on the drawing file and included in the drawing].

FROM [sender's name]

COPY TO [copy recipients, if any]

File - C:\Users\232\Desktop\TM-PM-07 Electronic File Transfer Record (CD Comments) (2).doc

BIM PROJECT EXECUTION PLAN
VERSION 1.1 DRAFT
EEB HUB BUILDING 661 & 7R
AT THE PHILADELPHIA NAVY YARD
PSU# 03-03808.00



DEVELOPED BY:

BALFOUR BEATTY (BB), KIERAN TIMBERLAKE(KT), AND PENN STATE- OFFICE OF PHYSICAL PLANT (PSU-OPP)

25 JULY 2012

Please direct any questions about this template to Kurt Maldovan (kmaldovan@balfourbeattus.com). Please do not contact any of the other contributors pertaining to this template.

BIM Project Execution Plan

VERSION 1.1 DRAFT FOR
EEB HUB BUILDING 661 & 7R
DEVELOPED BY: BB, KT, PSU-OPP

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1.0 BIM PROJECT EXECUTION PLAN OVERVIEW

A BIM Project Execution Plan outlines the overall vision along with implementation details for the team to follow throughout the project. The overarching goal for a BIM Project Execution Plan (BIM Plan) is to stimulate and direct additional communication and coordination by the team members during all phases of a building project. This plan defines the scope of BIM implementation on the EEB HUB project by: identifying the process flow for BIM tasks, defining the information exchanges between parties, and describing the required project and company infrastructure needed to support the implementation. By developing a BIM Plan, the project and project team members look to achieve the following values:

- Understand and communicate of strategic goals for project BIM implementation
- Assign and understand roles and responsibilities for BIM implementation
- Design an execution process which is well suited for each project stakeholder's typical business practices and organizational workflows
- Outline additional resources, training, or other competencies necessary to successfully implement BIM for the intended uses
- Provide a benchmark for describing the process to future project participants
- Define contract language to ensure that all project participants fulfill their obligations
- Provide a goal for measuring process throughout the project

1.1.1.OWNERSHIP AND USE OF BIM MODEL AND DATABASE

This BIM Model is an instrument of service and is considered to be a component of Design and Construction Documents governed by Article 1.1.10 of the Owner/ Professional Agreement (Form 1-P) and Article 1 of the Owner/Contractor Agreement (Form1-C) without exception. In addition, each Model Element Author (MEA) contributing to the BIM model(s) and database agrees to provide all project stakeholders and Penn State (Owner) a non-revocable, exclusive license to utilize any and all intellectual property provided by each MEA contained within this BIM for the sole purpose of completing the design, construction and other uses as stipulated and/or implied by the executed Owner/ Professional Agreement and Owner/Contractor Agreement for this project.

1.1.2 RIGHT OF RELIANCE

The BIM Model produced by the project stakeholders associated with the Design Team will serve as the basis of design and is considered a **Design Intent Model** only. The model prepared by the Design Team will be used by [CONTRACTORS] to prepare a **Means and Methods Model**. This Right of Reliance pertains to all models and applications associated with the model and associated applications.

The Construction Team may rely on the accuracy of the model(s) prepared by the Design Team in accordance with traditional Standard of Care provisions that apply and govern the design and construction of comparable buildings in two (2) - dimensional design formats and methods.

Conversely, the Design Team may rely on the accuracy of the model(s) prepared by the Construction Team in accordance with traditional Standard of Care provisions that apply and govern the preparation of shop drawings, fabrication drawings, sequencing and other instruments used to convey the means and methods under the control of [CONTRATOR(S)], its subcontractors, consultants and other agents working on this project.

As mutually agreed by all parties including [Professional], [CM], [CONTRATOR(S)] and Owner, nothing shall be construed by the content and/or preparation of the associated model(s) as a warranty or guarantee of accuracy and/or completeness by the Design Team. Standard and traditional procedures for design, documentation, means and methods, shop drawing submittals, verification by the contractor, requests for information in question, etc**. shall apply** to the design, construction and construction administration of the project.

The construction manager, CONTRATOR(S) and subcontractors shall be solely responsible for means and methods and the execution of the Design Intent Model through the execution, preparation and management of delegated design, the Means and Methods Model(s), fabrication, installation and construction.

1.2. Record Model & As-Built Model Development Process

The following process is defined for the Record Model and the As-Built Model. Specific details to be confirmed by the project team:

- [Professional] is responsible for the initial Design Intent Model. [CONTRATOR(S)] are responsible for the initial Means & Methods Model.
- [Professional] to provide the coordinated Design Intent Model to [CONTRATOR(S)] to be used for the creation of the Means & Methods Model.
- [CONTRATOR(S)] will update the Means & Methods Model with all as-built conditions to form the As-Built Model deliverable in Navisworks.
- [Professional] will revise the Design Intent Model with all design revisions (architectural, structural, and MEP) to form the Record Model deliverable in Revit.
- [CONTRATOR(S)] will convert the Navisworks As-Built Model ~~into [a file type readable in Revit]~~ where [Professional] will validate and revise to produce a field accurate Record Model.
- All 2D Record and As-Built Documents will be produced from their respective models.

2.0 PROJECT INFORMATION

2.1. Project overview information

Facility Owner	EEB HUB / The Pennsylvania State University
Project Name	EEB HUB Building 661 and 7R Building
Project Location	Philadelphia Navy Yard 4900 South Broad St. Philadelphia, PA 19112
Contract Type/Delivery Method	Design-Bid Build/ CM Agency/ Multi-Prime

2.2. Brief Project Description:

Located within the Historic Core district at the Philadelphia Navy Yard, the EEB HUB project is comprised of a renovation to an existing structure and a new building on a lot directly across the street. The renovation will transform the former 38,000 SF navy gymnasium into an energy efficient office and demonstration showroom for the Greater Philadelphia Innovation Cluster. Across the street and adjacent to a new park, a new 25,000 SF building housing classrooms and academic office building will be developed on an open site that previously served as a ball field for the gymnasium.

2.3. Additional Project Information: [If applicable]

- Seeking LEED Gold/ Platinum Certification

Project Numbers

Project Information	Project Number
PSU Building Number	TBD (9999999)
PSU Project Number	03-03808.00
Tririga Project ID (Job Number)	1447088
Kieran Timberlake	830
Balfour Beatty Construction	20017501/ 11884000

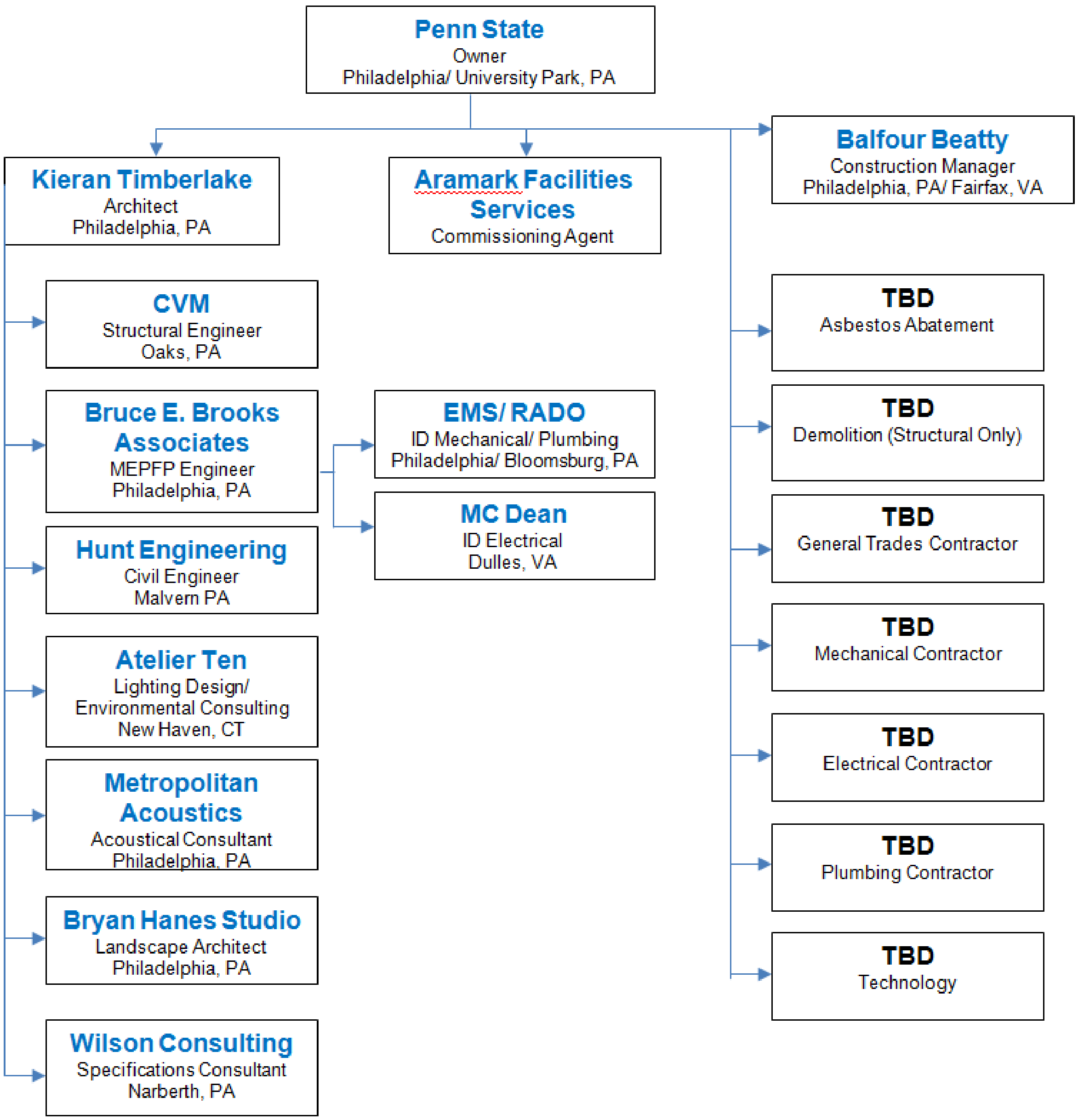
2.4. Project Schedule / Phases / Milestones

Project Phase / Milestone	Project Stakeholders Involved
Preliminary Planning	A/E, CON, OPP
Conceptualization	A/E, CON/ OPP
Criteria Design	A/E, CON, OPP
Detail and Implementation Documents	A/E, CON/ OPP
BOT Approval	OPP
Construction/ Construction Admin	A/E, CON/ OPP
Project Closeout	A/E, CON, OPP

Project Schedule can be accessed via MySmartPlans or SECTION L- PRELIMINARY SCHEDULE as referenced in the DIV 00 Packet.

3.0 KEY PROJECT CONTACTS

3.1. Organization Chart



3.2. Penn State Project Team

The following client team staff members are providing leadership for BIM Execution on behalf of PSU:

Role	organization	name	location	email	phone
Construction project manager	PSU OPP				
BIM manager	PSU OPP				
EEB HUB/ BIM POC	PSU- EEB HUB				
EEB HUB/ BIM POC	PSU- EEB HUB				
Icon Lab POC	PSU-CIC				
Sharepoint POC	EEB HUB				
PR MGR/ Scheduling POC	EEB HUB				
Icon Lab	Icon Lab				

3.3. Design Team

The following design consultants are providing professional services for this project. For each firm, key leadership personnel listed include Principals, Managers, Architect/Engineers, and Designers. BIM Managers/Coordinators are also listed below. This list will be updated as needed as additional team members are assigned to the project. Members of the Design Team include:

Role	organization	name	location	email	phone
Architecture project managers(s)	KieranTimberlake				
Architecture BIM manager(s)	KieranTimberlake				
Architecture Design lead	KieranTimberlake				
Civil Information Model lead	Hunt Engineering				
Civil Project Manager	Hunt Engineering				
Electrical / Telecom BIM Lead	Bruce E Brooks Associates				
Electrical / Telecom Project Manager	Bruce E Brooks Associates				
Fire Protection BIM Lead	Bruce E Brooks Associates				
Fire Protection Project Manager	Bruce E Brooks Associates				
Mechanical BIM Lead	Bruce E Brooks Associates				
Mechanical Project Manager	Bruce E Brooks Associates				
Structural BIM Lead	CVM				

Structural Project Manager	CVM				
Energy Modeling Lead	Atelier Ten				
Energy Modeling Project Manager	Atelier Ten				
ID MP Project Manager	EMS				
ID E Modeling Lead	MC Dean				
IE MP Modeling Lead	Rado				

3.4. Construction Team

The following construction specialists are providing professional services for this project during the design phase and construction. This list will be updated as needed as additional team members are assigned to the project. Members of the Construction Team include:

Role	organization	name	location	email	phone
Design Project Manager	Balfour Beatty				
BIM Manager	Balfour Beatty				
Construction Project Manager	Balfour Beatty/ Heery				
Estimating Lead	Balfour Beatty				
Project Executive	Balfour Beatty				

3.5. Owner Contracted Consultants

The following construction specialists are providing professional services for this project during the design phase and construction on behalf of PSU as a sole source provider.

Role	organization	name	location	email	phone
Commissioning	ARAMARK				
Consultant	TBD				
IBM/ Maximo POC	IBM				
Autodesk POC	Autodesk				

4.0 PROJECT BIM OBJECTIVES / PROJECT BIM USES

4.1. Project BIM Goals / Objectives

The following goals have been established for BIM execution associated with the project:

Goal Description	Potential BIM Use/ Process	Project Value
Value added objectives		
Energy efficiency	Energy Analysis/ Operations and Maintenance	I
Repeatability of the Process	PxP Documentation	R
Standardized Technology Assemblies/ Kit of Parts	Design Authoring	S
Integrated Design	Collaboration/ PxP	C
Accurate Information	Record Model/ Asset Management	T
Accurate Existing Condition	Existing Conditions Modeling (Laser Scanning)	S, L
Design Feedback	Design Reviews	C
Document Monitoring Equipment in Model	Building System Analysis (Compare Design to Actual Conditions)	S
Estimated Energy Projections	Energy Analysis/ Lighting Analysis/ Mechanical Analysis/ Civil & Stormwater Analysis	$, T
Model Granularity (LoD)	Maintenance and Scheduling (Targeted Building Operations Manual)	C, T
Clear Deliverable Expectations	PxP Documentation	T, R
Transparency/ Demonstration/ Energy Awareness		L
Subcontractor Integration	Construction System Design/ Constructability Reviews	C
Real time Embodied Energy Calculator (Sustainability) (OPTIONAL)	LEED (Sustainability) Evaluation	S, T
Reducing Bid Variability	Design Coordination	$, C
Document BIM Capabilities in Surrounding Area	Survey	L, R

C- Collaborative Environments

I- Influence

L- Learning

R- Repeatability

S- Systems Integration

T- Time Reliability

$ - Cost Certainty

4.2. Project BIM Uses

A BIM Use is defined as a task or procedure on a project which can benefit from the application and integration of BIM technologies and add value to the overall project.

BIM Use Classification	Definition
Yes	Required
Targeted	Project team should make attempts to pursue BIM Use. Further use definition required by PSU OPP. Uses are expected to be pursued, but degree of implementation is not yet defined. Additional cost may be incurred above base contract agreement.
Maybe	Project team should make no additional effort to pursue this BIM use. No approval is required for nonperformance.
No	BIM use not pursued at this time

The following BIM Uses marked **Yes** are the minimum requirement for BIM Use during the project. Uses marked with "A" indicate Additional Cost or Effort and will be discussed with the client (PSU-OPP).

Blue Italic Rows are added per PSU OPP V2.0 BIM PxP

Blue Rows are uses added to the phase, which are typically not included in that phase per the BIM PxP

4.2.1. BIM USES DURING PLANNING

PLAN (Stage done)		IN KT	IN BB	OPP	Yes	No	Targeted	Maybe
Energy Analysis	Conduct energy assessment for building design, inspect building energy standard compatibility, and optimize proposed design to reduce facility lifecycle costs.	A	A		X			
Existing Conditions Modeling	Develop a 3D model of the existing conditions for a site, facilities on a site, or a specific area within an existing facility (3D laser scanning prior to construction)					X		
Site Analysis	Evaluate site to determine if site meets the required criteria according to project requirements, technical factors and financial factors	Y			X			
Programming	Analyze spatial program and requirements and accurately assess design performance in regard to space standards and regulations	Y			X			
4D Modeling	Plan project construction sequence		A					X
Cost Estimation (Quantity)	Trend quantities (during planning)	Y	Y		X			
BIM Execution Kickoff and Project BIM Setup		Y	Y		X			

4.2.2. BIM USES DURING DESIGN

DESIGN		IN KT	IN BB	OPP	Yes	No	Targeted	Maybe
Design Intent Model Development (Design Authoring) (A/M/E/P/FP/S/C)	Develop model based on criteria that is important to the translation of the building's design	Y			X			
Design Reviews	Review design development/ progress and require feedback based on design		Y		X			
3D (Design) Coordination	Determine and resolve major system design conflicts prior to construction		Y		X			
Energy Analysis	Analyze model based on energy design specifications	Y			X			
Model Commissioning Verification (PROCESS by OPP)	Organize commissioning data into model	A	A				X	
Structural Analysis	Analyze model based on structural specifications	Y			X			
Mechanical (CFD/ CFM) Analysis	Analyze mechanical systems based on design specifications	Y			X			
Lighting Analysis	Analyze lighting systems based on design specifications	Y			X			
LEED Evaluation	Organize information for USGBC							X
Code Evaluation	Streamline Code Review							X
Storm Water Analysis	Analyze storm water systems and runoff	Y			X			
Embodied Energy Analysis	Analyze embodied energy	Y			X			
4D Modeling	Plan project construction sequence		Y		X			
Cost Estimation (Quantity)	Trend quantities (during design)	Y	Y		X			
Existing Conditions Modeling	Develop a 3D model of the existing conditions for a site, facilities on a site, or a specific area within an existing facility (3D laser scanning prior to construction)	A	A	A			X	

4.2.3. BIM USES DURING CONSTRUCTION

CONSTRUCT		IN KT	IN BB	OPP	Yes	No	Targeted	Maybe
Construction Model Development	Develop model based on criteria that is important to the translation of the building's construction	A	A				X	
Constructability Reviews	Evaluation construction feasibility		Y		X			
3D (Construction) Coordination	Determine and eliminate system conflicts prior to installation		Y		X			
Model Commissioning Verification (PROCESS by OPP)	Verify commissioning data in model	A	A	X			X	
4D Modeling	Plan project construction sequence		A					X
Site Utilization Planning	Visually depict site conditions		Y		X			
Cost Estimation	Trend quantities (during construction)					X		
Digital Fabrication	Prefabricate objects (CNC/ Pre-assembly/ modularization)	A	A				X	
3D Control and Planning	Use model to layout/ install equipment/ production tracking		A					X
Construction System Design	Plan and design temporary components and safety systems		A				X	

4.2.4. BIM USES PRIOR TO PROJECT TURNOVER

OPERATE	Objective	IN KT	IN BB	OPP	Yes	No	Targeted	Maybe
As-Built (Record) Modeling	Capture (as-designed) installed conditions during construction	Y	A				X	
Maximo System Integration(Asset Management Tool/ Database Exchange)	Integrate model with existing Enterprise Asset Management System		A	A			X	
Asset Management	Track manufacturer/ commissioning/ maintenance records		A				X	
Continuous Commissioning	Commissioning facility based off of end user requirements		A					X
Space Management/ Tracking	Identify space use and track use throughout management of facility and movable assets	Y						X
BAS System Integration	Integrate model with existing Building Automation System							X
Model Quality Control	OPP Model Review			X	X			

5.0 ORGANIZATIONAL ROLES & STAFFING

5.1. PSU BIM Manager (Craig Dubler, PSU-OPP)

PSU will provide a BIM Manager to act as the owner BIM representative. This role will assist the appointed BIM Model Manager with the management and coordination of the BIM execution process on a project, as well as represent the end goal needs. This role will be the primary liaison between OPP and the project team for BIM related issues.

5.2. BIM Model Manager (Kurt Maldovan, BB; Andrew Cronin, KT)

The BIM Model Manager shall have sufficient BIM experience for the size and complexity of the project and shall have relevant proficiency in the proposed BIM authoring and coordination software. The BIM Model Manager shall serve as the main point of contact with PSU and the project team for BIM related issues.

During each phase of a PSU project, the model manager is required, but not limited to:

- Ensure completeness and accuracy for BIM Plan
- Ensure completeness and accuracy for overall project model
- Coordinate all updates for individual models, specialized models, and databases

5.2.1. RESPONSIBILITIES DURING PLANNING AND DESIGN (ANDREW CRONIN, KT; KURT MALDOVAN, BB; TOM HANNA, HUNT; JOSEPH MATJE, BEB; DAVID STOREY, CVM; WENDY MEGURO, A10)

- Act as lead contact for BIM related issues with all relevant project stakeholders and manage collaboration between all parties
- Lead the process of BIM Plan development as per requirements of the OPP BIM Addendum
  - Ensure project stakeholder compliance with the PSU approved BIM Plan
  - Develop, coordinate, publish, and verify all necessary configurations required for seamless integration of BIM Model(s) and facility data
- Facilitate the transfer of information on the file sharing exchange protocol
  - Assure that the design deliverables specified in the contract are provide in accordance with the required formats
  - Determine the project BIM geo-reference point(s) and assures all technical discipline models are properly referenced
  - Maintain BIM Model(s) and facility data standards and requirements
  - Assure proper BIM derived 2D documents conforms with the OPP Design and Construction Standard
  - Coordinate with project team to assure creation of required final BIM deliverables at project turnover
  - Coordinate with the OPP for facility management data and file exchange as needed
  - Lead meetings with lead BIM technicians and project BIM Team
  - Assemble composite design model for coordination meetings
  - Facilitate use of composite design models in design coordination/clash detections meetings and generate detection reports by the identification and resolution of all hard and soft collisions within the BIM Model(s)

  - Perform design reviews to test design in compliance with functionality and constructability requirements

5.2.2. RESPONSIBILITIES DURING PRE-CONSTRUCTION AND CONSTRUCTION (KURT MALDOVAN, BB; ANDREW CRONIN, KT; CONTRACTORS, TBD)

- Act as lead contact for BIM related issues with all relevant project stakeholders and manage collaboration between all parties
- Maintain and revise BIM Plan with additional construction information on an as needed basis
  - Ensure project stakeholder compliance with the PSU approved BIM Plan
  - Develop, coordinate, publish, and verify all necessary configurations required for seamless integration of BIM Model(s) and facility data during construction
- Coordinate and maintain the transfer of information on the file sharing exchange protocol
  - Coordinate the exchange of BIM model(s)and facility data between the Design Team and construction trades
  - Coordinate any field revisions that have been documented and updated to the Design Model with the Design Team in a timely manner
  - Coordinate with Lead BIM Technicians to integrate 3D fabrication models with the updated design model to ensure compliance with project deliverables
  - Maintain accurate As-Built/Record Model
  - Coordinate with contractor, design team, and commissioning agent to verify facility data before project turnover
  - Coordinate with the OPP for facility management data and file exchange as needed
- Lead meetings with lead BIM technicians and project BIM Team
  - Assemble composite construction model for coordination meetings
  - Facilitate use of composite trade models in construction coordination/clash detections meetings and generate detection reports by the identification and resolution of all hard and soft collisions within the BIM Model(s)
  - Coordinate construction sequencing and scheduling activities and assure they are integrated with the relevant BIM Model(s) and facility data
  - Perform constructability reviews

5.2.3. RESPONSIBILITIES DURING POST CONSTRUCTION (CRAIG DUBLER, PSU-OPP; KURT MALDOVAN, BB; ANDREW CRONIN, KT; CONTRACTORS, TBD)

- Meet with facilities management group for review of turnover documents
- Finalize BIM As-Built/Record Model and facility data
- Verify model accuracy and completeness in accordance to OPP Owner Requirements
- Facilitate the transfer of information on the file sharing exchange protocol
- Hand over BIM As-Built/Record Model(s) and facility data to OPP for use in operations

5.3. Lead BIM Technicians (Andrew Cronin, KT; Tom Hanna, Hunt; Joseph Matje, BEB; David Storey, CVM; Wendy Meguro, A10; Contractors, TBD)

Each major design discipline and Contractor(s) shall assign an individual to the role of lead BIM Technician for the duration of the project. These individuals shall have the relevant BIM experience required by the complexity of the project. As a minimum, the Lead BIM Technician would have the following responsibilities for their discipline:

- Act as Lead BIM contact for the duration of the project
- Maintain and manage integrity of model, including:
  - Coordinate BIM development, standards, data requirements, etc. as required
  - Lead the technical BIM team in its documentation and analysis efforts
  - Exchange files between other disciplines
  - Upload and maintain models to file exchange server
  - Prepare model for review, as required
- Ensure development and documentation of clash resolution
  - Maintain a continuous interface with the BIM Model Manager
  - Participate in coordination and BIM technology meetings
- Coordinate trade items into the Record Model and/or As-built Model, in accordance with project BIM Plan

6.0 DESIGNING THE BIM EXECUTION PROCESS

6.1. Mapping the BIM Execution Process [If Applicable]

A process diagram for the overall use of BIM on the project has been developed for the project. The attached diagrams summarize the workflow of the BIM Uses and their associated information exchanges for the project.

The BIM Execution Process Diagram for this project can be found in **Attachment 1** of this document. The EEB HUB Research team will work with Penn State, BB, and KT to define format for this Level 1 process as well as provide input on developing detailed Level 2 Process Maps. A descriptive example for Clash Detection is included in **Attachment 4** [of the BIM PxP]. The goal of ongoing EEB HUB Research is to use these Process guides to define a standard or repeatable process. The EEB HUB Research team will identify a lead for each process to work with the leads from KT and BB.

6.2. Developing Information Exchanges

The project team should document the information exchanges created as part of the planning process when creating the BIM Plan. The level of development (LOD) for each model element is based on the model content criteria established by the AIA Document E202, Building Information Modeling protocol Exhibit. The LOD will assist in determining the level of involvement for each project stakeholder from project conception through project turnover.

The LOD Matrix for the project is located in **Attachment 2** of this document. The content for each LOD is described as follows:

Level of Development	Description
LOD 100 Schematic Design (Conceptualization)	The equivalent of conceptual design, the LOD 100 model usually consists of overall building massing designed to perform whole building type analysis including building orientation, square foot costs. LOD 100 will also pertain to 2D representation of elements as required by the 2D Construction Documents which may include drawings, narratives, and hand-built models.
LOD 200 Design Development (Detail & Implementation Documents)	Similar to schematic design or design development, the LOD 200 model would consist of generalized systems including approximate quantities, sizes, shapes, location, and orientation. The LOD 200 mode(s) are typically used for analysis of defined systems and general performance objectives. LOD 200 model(s) should include attributes and parameters defined by the owner in the Owner Requirements document and BIM Plan.
LOD 300 Construction Documentation (Construction/ Construction Administration)	Model will include elements equivalent to traditional construction documents and shop drawings. LOD 300 models are well suited for estimating as well construction coordination for clash detection, scheduling, and visualization purposes. LOD 300 model(s) should include attributes and parameters defined by the owner in the Owner Requirements document and BIM Plan.
LOD 400 Construction Administration/ Shop Drawings (Construction/ Construction Administration)	Model elements are modeled as specific assemblies which are accurate in terms of quantity, size, shape, location, and orientation. LOD 400 model(s) are virtual representations of the proposed elements and considered to be suitable for construction, fabrication, and assembly. This LOD is most likely to be used by specialty trade contractors and fabricators to build and fabricate project components including MEP systems.
LOD 500 Project Completion/ Record Drawings/ As-Built Conditions	Model elements represent the project as it has been constructed, including as-built conditions. The model is configured to be the central data storage for integration into the building maintenance and operations system(s). LOD 500 Model(s) will include completed parameters and attributes specified in the Owner Requirements document and BIM Plan. At the completion of construction, the BIM model(s) will be finalized, linked, and cross referenced.
LOD 510, 520, 530, 540	Model elements represent the project as it has been constructed, including as-built conditions. LOD 510, LOD 520, LOD 530, and LOD 540 models will contain LOD 100, LOD 200, LOD 300, LOD 400 facility and geometry data respectively and will be configured to contain the Operations and Maintenance manuals, warranty information, submittal information, and/or any other documents as applicable or required.
LOD 550 Owner Reserved	Owner reserved, LOD 550 model elements will not be generated during planning, design, or construction.

7.0 OWNER FACILITY DATA REQUIREMENTS

7.1. Asset Attribute Information

Working with the University end-users, end-maintainers, and end-operators, the OPP has developed an OPP Owner Requirements document which includes the required asset attribute data and level of detail needed for particular assets at PSU.

The Asset Attribute Information list for the project is located in **Attachment 3** of this [BIM PxP] document [or section K.3 Facility Attribute List].

8.0 COLLABORATION PROCEDURES

8.1. Collaboration Strategy

The project team will communicate using an electronic Project Management Information System (PMIS). The goal of the PMIS is to create transparency among all team members.

The selected PMIS is MySmartPlans. MySmartPlans is a comprehensive data management solution that includes servers located in a security collocation facility with unlimited project data capacity, bandwidth, and unlimited user site licenses, full backup, redundancy and interfaces to existing systems.
Documents posted to MySmartPlans are fully searchable, bookmarked and indexed, optimized for file size, enabled for mark-up and review, and will meet project naming conventions.
Electronic vaulting of project information will occur monthly and include all project modules.

Models and Drawings will be uploaded to their respective repositories on a bi-weekly basis. Further information will be developed as this system is deployed. The MySmartPlans system provides full data backups, record storage, and an audit trail of model uploads/ downloads.

8.2. Meeting Procedures

Meeting Type	Project Stage	Frequency	Participants	Location
BIM Requirements Kick-Off	Planning	Once	Senior Management BIM Management Staff	EEB HUB 101/ KT Office
BIM Plan Review	All	Bi-Monthly	Senior Management BIM Management Staff PSU BIM Coordinator	EEB HUB 101/ KT Office
3D Design Coordination	DD/CD	Bi-weekly	Design Team	EEB HUB 101/ KT Office
3D Construction Coordination	Construction	Bi-weekly	Construction Team	EEB HUB 101
Mechanical Space Review	Design/Construction	TBD	PSU Work Control Center Design Team Construction Team	EEB HUB 101

8.3. Model Delivery Schedule of Information Exchange for Submission & Approval

Models officially transferred bi-weekly between design consultants

Progress models posted consistently to PMIS

PDF Drawings will be posted to PMIS and prior to design review, a redline review and drawing compare will occur

At intervals as determined by the project team, working design models will be posted to Sharepoint for EEB HUB's review

Design Review models will be posted to Sharepoint and access given on PMIS

Construction CONTRATOR(S) and Subcontractors will have access to models at a frequency to be determined by the project team.

8.4. Electronic Communication Procedures

USER PERSONA ACCESS RIGHTS

USER PERSONA	COMPRISED OF	FULL PMIS ACCESS	SELECT PMIS ACCESS	SHAREPOINT ACCESS
Researcher	EEB HUB		x	x
Owner	PSU-OPP	X		x
DB Team	KT, Design Consultants, BB	X		x
Procurement	Solicited Contractors		x	
Contractors	Selected Contractors	X		TBD

Users can request access via online form and approvals by project team

9.0 QUALITY CONTROL PROCEDURES

9.1. Overall Strategy for Quality Control

The purpose of this process is to ensure project teams are using best practices in the development and file exchange of models and facility data. This is an ongoing process, which is to be conducted by the project team and validated by the University Project manager at both project milestones and at random intervals to ensure that each model is being constructed in accordance with the OPP BIM Standards and is suitably modeled for its intended use. The goal is to ensure that there are no unresolved issues during construction or any significant loss of data upon transfer of as-built models and record documents at facility turnover.

Each BIM Manager will be responsible for running quality control checks on their model(s) on a consistent and frequent basis. For issues involving other disciplines, the issue shall be made known to the corresponding BIM Manager.

9.2. Quality Control Checks

CHECKS	DEFINITION	RESPONSIBLE PARTY	RECOMMENDED PROJECT MILESTONES
Standards	Ensure that PSU BIM Standards and Guidelines have been followed	OPP	Criteria Design Detail & Implementation Documents Construction Operations
Visual	Ensure there are no unintended model components and the design intent has been followed	[ARCH] [CM]	Criteria Design Detail & Implementation Documents Construction Operations
Model Integrity	Ensure that the Facility Data set has no undefined, incorrectly defined, or duplicated elements; ensure a reporting process and corrective action plans have been developed for noncompliant elements	[ARCH] [CM]	Detail & Implementation Documents Construction Operations
Model Commissioning	Provide report verifying model and database compliance with defined quality control procedures for component LOD and stakeholder information	OPP [CM]	Detail & Implementation Documents Construction Operations
[Additional]			

9.3. Quality Control Procedures

BIM Managers to define an appropriate quality control procedure for the project. The following is an example of a quality control procedure and must be validated for the project:

- Review random 10% of documented information
- If percent error is less than 3%, document reasons for error and revise throughout remaining model
- If percent error is between 3-5%, review additional 15% of randomly selected documented information.

    - If percent error is greater than 3% after 25% review, project team to revise and resubmit information, as to not delay downstream user progress
    - If percent error is less than 3% after 25% review, document reasons for error and revise throughout remaining model
- If percent error is greater than 5%, project team is to revise and resubmit information, as to not delay downstream user progress

9.4. Model Accuracy and Tolerances

Model(s) should be as accurate as possible. Dimension tolerances should be set at 1/8" to facilitate the accuracy of the model.

10.0 TECHNOLOGICAL INFRASTRUCTURE

10.1. Software

BIM Use	Discipline (if applicable)	Software
Design Authoring	Architectural	Autodesk Revit 2013
Design Authoring	Civil	Autodesk Civil 3D 2008
Design Authoring	Electrical/ Telecom	Autodesk Revit 2013
Design Authoring	Fire Protection	Autodesk Revit 2013
Design Authoring	Mechanical	Autodesk Revit 2013
Design Authoring	Structural	Autodesk Revit 2013
Design Authoring	Energy Modeling	Autodesk Revit 2013/ XXXX
Design Reviews	Architectural	Autodesk Revit 2013/ Autodesk Navisworks Manage 2013
3D Design Coordination	Architect Consultants	Autodesk Revit 2013/ Autodesk Navisworks Manage 2013
Constructability Model	Contractor	Autodesk Revit 2013/ Autodesk Navisworks Manage 2013
Energy Modeling	Architect/ Consultant	Equest
3D Construction Coordination	[Contractor] [CM]	Autodesk Revit 2013/ Autodesk Navisworks 2013
3D Construction Coordination (Viewing)	[Contractor] [CM]	Autodesk Revit 2013/ Autodesk Navisworks 2013
Constructability Reviews	[Contractor] [CM]	Autodesk Revit 2013/ Autodesk Navisworks 2013
Record Model	[Architect] [Owner]	Autodesk Revit 2013/ Autodesk Navisworks Manage 2013
As-Built Model	[Contractor] [Owner]	Autodesk Revit 2013/ Autodesk Navisworks Manage 2013

[Additional BIM Use and Applicable Software]	

Software object enablers and information related to latest release will be posted to PMIS

10.2. Computers / Hardware

Recommended Hardware: Quad Core Processor / 8-12 GB RAM / Windows 7

10.3. File Transfer Protocol

An electronic PMIS (Project Management Information System) will be established per project for the purpose of efficient and timely transfer of model files and coordination files. This workspace will provide a collaborative location where the current contract CAD/Revit files, coordination files, and fully coordinated submittal files will reside. Each BIM coordination team member obtains data from this location. Project team members are to upload updated copies of their coordination files, provide notification, and to make collaboration comments/annotations as often as necessary to maintain project schedule. Refer to Section 8.1 for more information on the Project Collaboration Strategy.

11.0 MODEL STRUCTURE & DATABASE STRUCTURE

11.1. File Naming Structure

File Naming Convention:

Project Number_Project Description_Discipline.File Extension

830_Bldg661_A.rvt

830_Bldg661_M.rvt

830_Bldg661_E.rvt

830_Bldg661_P.rvt

830_Bldg661_C.dwg

830_Bldg661_S.rvt

830_Bldg661_FP.rvt

830_Bldg661_L.rvt (Site Model)

LINK_Bldg661_S

830_Bldg7R_A.rvt

830_Bldg7R_M.rvt

830_Bldg7R_E.rvt

830_Bldg7R_P.rvt

830_Bldg7R_C.dwg

830_Bldg7R_S.rvt

830_Bldg7R_FP.rvt

830_Bldg7R_L.rvt (Site Model)

LINK_Bldg7R_S

Link models origin to origin

Each Link is on its own workset

Example Workset Naming: LINK_Bldg7R_S

11.2 FILE LINKING CONVENTIONS

- Use absolute paths and avoid using mapped drives
- Set file links to OVERLAY
- Link files ORIGIN to ORIGIN
- Confirm that 2D files are placed at the appropriate level
- Place links on appropriate work sets as determined appropriate by project (“Linked Revit - Arch”; “Linked – CAD”)

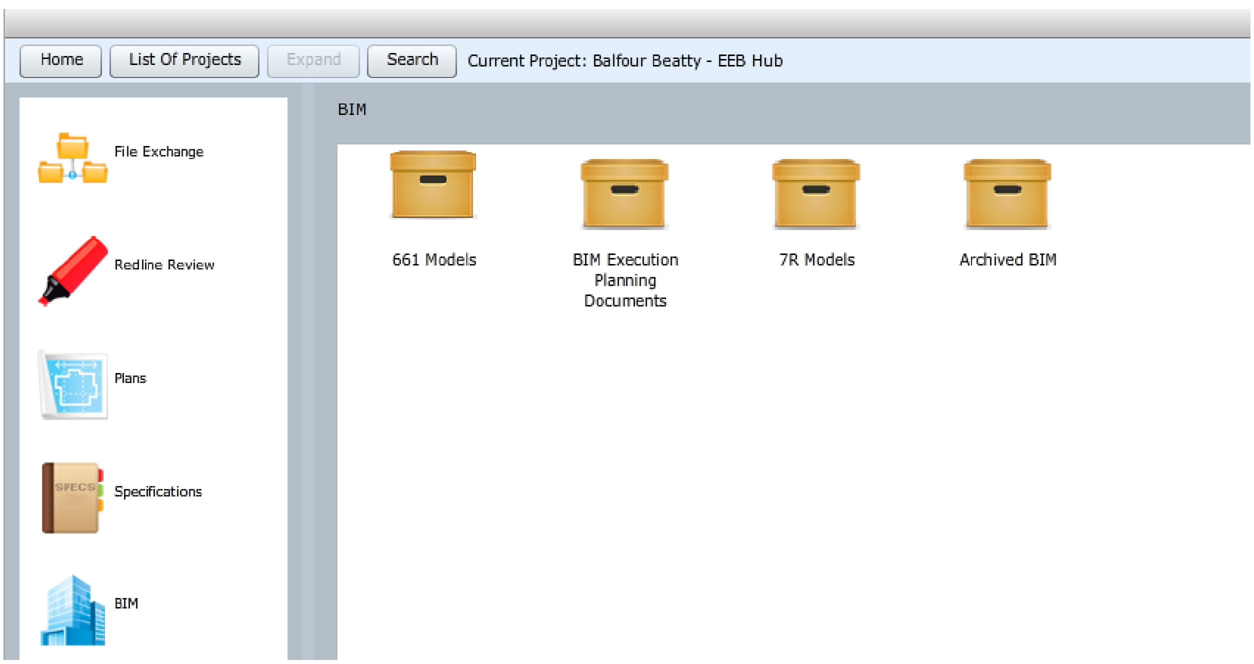
11.3 COLLABORATION PROCEDURES

The following section lists the typical procedures for information exchanges, model sharing, and coordination throughout a project.

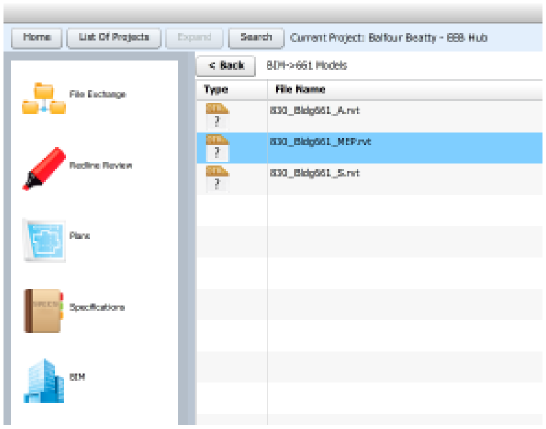
- The model(s) shall be synchronized between all disciplines
- All project stakeholders and responsible parties must post their models to the designated shared serve on a bi-weekly basis as specified. Before the model(s) are shared and/or transferred, the model should be audited to conform to the following standards:
  - Verification of model origin and elevation. Projects level shall correspond with real world elevations
  - Resolution of as many conflicts and warnings and possible
  - Confirmation of file naming conventions, as specified in the BIM Plan

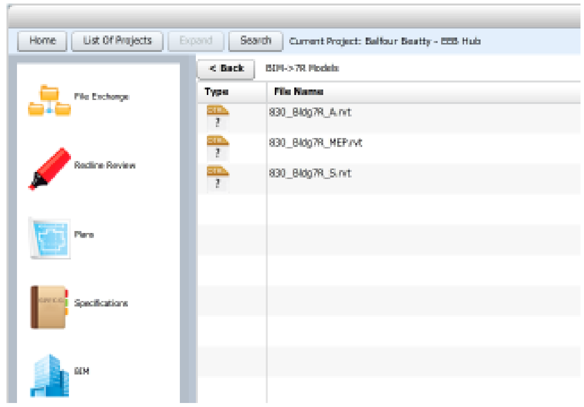
File Transfer and Collaborative workspace

Vaults within MySmartPlans are established for the purpose of efficient and timely transfer of model and database files. This workspace will provide a collaborative location where the current contract CAD/Revit files, coordination files, and fully coordinated submittal files will reside. Each BIM coordination team member stores and obtains data from this location. Project team members are to upload updated copies of their files, provide notification, and to make collaboration comments and annotations as often as necessary to maintain project schedule.

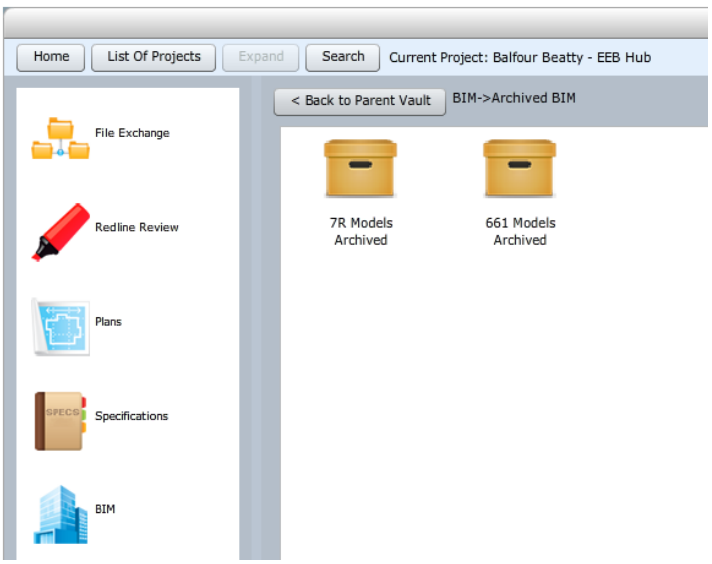


MySmartPlans Dashboard- showing BIM Vaults





Active models are stored in the BIM/ 661 Models and BIM/ 7R Models Vaults



Archived Models are stored in the BIM/ Archived BIM Vaults

To assist in meeting facilitation, a collaborative work environment must be dedicated for design review and coordination. Prior to establishment of the BIM Trailer on the construction site, meetings may be held at either the OPP BIM Room or the design team's office. The CM or Contractor will be responsible for providing and installing the collaborative workspace and it should be located at the construction site to coordinate fabrication models with the respective trades.

Maximum achievable BIM technology shall be used to view documentation and models, interactively create mark-ups, archive models and facility data, and convert them to RFIs or other relevant reference documents.

Posting Protocol- Every week/ two weeks (confirm with consultants) post current state/ Cost Model posted monthly. Track model changes in project browser (splash page).

11.4 Model Structure

11.4.1 ARCHITECTURE MODEL- SEE 11.1

11.4.2 STRUCTURAL MODEL- SEE 11.1

11.4.3 MEP MODEL- SEE 11.1

11.5 Measurement and Coordinate System

Feet/ Inches

12.0 PROJECT DELIVERABLES

The BIM deliverables indicated below are required to be submitted with the standard phase deliverables for each project phase. The BIM Plan should establish the responsible parties and corresponding tasks for each deliverable. The level of development for each BIM deliverable should be, at a minimum, sufficient to fulfill the 2D document submission requirement.

12.1. Design Submittal Requirements

BIM Submittal Item	Project Stage	Format	Notes
BIM Project Execution Plan	Schematic Design	.pdf	
Design Model(s) (Design Development)	Documentation	.rvt .nwd	See Information Exchange Worksheet to ensure the proper information is contained in the model.
Design Drawings (Design Development)	Documentation	.pdf	Documents to be printed directly from model. Documents to be stamped and signed in traditional practice to comply with local permitting requests.
Interference Check Report (Design Development)	Documentation	.pdf	Include with all design submittals
Design Model(s) (Construction Documents)	Construction Documents	.rvt .nwd	See Information Exchange Worksheet to ensure the proper information is contained in the model.
Design Drawings (Construction Documents)	Construction Documents	.pdf	Documents to be printed directly from model. Documents to be stamped and signed in traditional practice.
Interference Check Report (Construction Documents)	Construction Documents	.pdf	Include with all design submittals
Model Attribute Report	Construction Documents	.pdf	Include with all design submittals
PSU Facility Data Compliance Report	Construction Documents	.pdf .xls	PSU-OPP to run compliance report upon design model submission and review
List of Submitted Files	Documentation/ Construction Documents	.pdf .xls	Include with all design submittals
[Additional BIM Deliverable]			

12.2. Construction Submittal Requirements

BIM Submittal Item	Stage	Format	Notes
BIM Project Execution Plan	Construction	.pdf	Contractor to Review BIM PxP and update version once on board
Interim Constructability Model(s) per Discipline	Construction	.rvt .nwd	See Information Exchange Worksheet to ensure the proper information is contained in the model.
Interference Check Report	Construction	.pdf .nwd	Report frequency to be coordinated/ . nwd model posted at a minimum- bi-weekly
Construction Submittals	Construction	.pdf	To be coordinated
Model Attribute Report	Construction	.pdf	To be coordinated
PSU Facility Data Compliance Report	Construction	.pdf .xls	PSU-OPP to run compliance report upon design model submission and review
List of Submitted Files	Construction	.pdf .xls	To be coordinated
[Additional BIM Deliverable]			

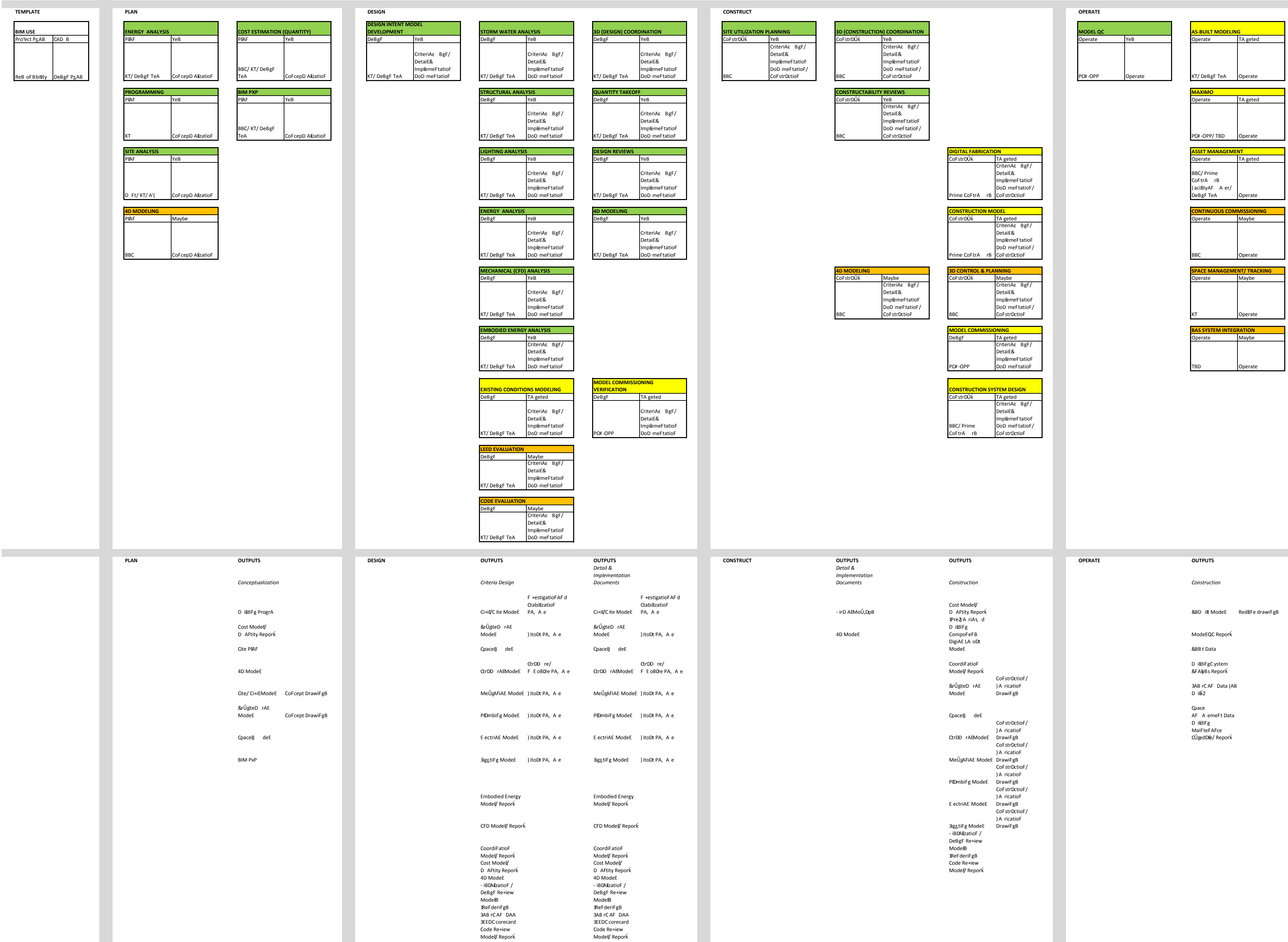
12.3. Project Closeout Submittal Requirements

BIM Submittal Item	Stage	Format	Notes
As-Built (Record) Model	Close Out	.rvt .nwd	See Information Exchange Worksheet to ensure the proper information is contained in the model.
Record Drawings	Close Out	.pdf	Documents to be printed directly from model. Documents to be stamped and signed in traditional practice.
Facility Data Submittal	Close Out	.pdf .doc	To be coordinated
Construction Submittals	Close Out	.pdf	To be coordinated
List of Submitted Files	Close Out	.pdf	To be coordinated
[Additional BIM Deliverable]			

13.0 ATTACHMENTS

1. BIM Execution Process Diagram [From Section 6.1]
2. Information Exchange Worksheet [From Section 6.2]
3. Asset Attribute Information [From Section 7.1]
4. Process Definition Example [From Section 6.2]

Level 1: BIM Execution Planning Process
PSU GPIC 661 & (+) Buildings



BIM INFORMATION EXCHANGES - LEVEL OF DETAIL MATRIX

DRAFT

EEB HUB Building 661 and 7R **2/13/2012**

The Pennsylvania State University at the Philadelphia Navy Yard — EEB HUB

NOTE: This worksheet is a guide for the project team to define model creation scope of work and model level of development. Please review the Level of Development (LOD) definitions. The LOD will aid in determining the level of involvement of the project stakeholders from design through facility turnover. Th worksheet is intended to guide the project team in achieving project goals, accomodate required BIM uses, and meet schedule requirements for the project. This worksheet will be used to audit BIM progress throughout the project and to coordinate work efforts.

Level of Development (LOD) is the level of completeness to which a model element is developed at the end of each project phase.

LOD 100: Schematic Design; overall building massing; whole building analysis (volume, orientation, square footage costs)

LOD 200: Design Development; generalized systems/assemblies (approximate quantities, size, shape, location, orientation); selected system performance analysis

LOD 300: Construction Documentation; generation of traditional CD's and shop drawings; analysis and simulation of detailed elements/systems; includes attributes and parameters defined by PSU

LOD 400: Construction Adiminstration/Shop Drawings; includes specific assemblies which are accurate in terms of quantity, size, shape, location, and orientation; virtual representations of the proposed elements, suitable for construction, fabrication, and assembly

LOD 500: Project Completion/Record Drawings/As-built Conditions; model is configured to be the central data storage for integration into the building maintenance and operations systems; includes completed parameters and attributes as specified by PSU.

LOD 510, 520, 530, 540 LOD 510, LOD 520, LOD 530, and LOD 540 models will contain LOD 100, LOD 200, LOD 300, LOD 400 facility and geometry data respectively and will be configured to contain the Operations and Maintenance manuals, warranty information, submittal information, and/or any other documents as applicable or required.

Other: Narratives, drawings, hand built models, etc.

Please refer to the project specific BIM Plan or the OPP Bim Standards & Guidelines for the level of development required for each model element. Typically any project element under X Inches in size will not be modeled. All elements above X inches should be included in the design model as an "object" unless otherwise specified below.

Each project stakeholder should review, comment, and confirm work efforts and LOD. If an effort has been misassigned, omitted, duplicated, or incorrectly included, please notify EEB BIM Integrator.

Model Element Author

Abbreviaton	Firm/Role	Discipline
H	Hunt	Civil
KT	Kieran Timberlake	Architectural
BBC	Balfour Beatty	CM
BBA	Bruce E Brooks Associates	MEPF
CVM	CVM	Structural
A10	Atelier Ten	Energy

The Pennsylvania State University KT/ BB/ PSU-OPP

		Design Intent Model						Means and Methods Model						Integration with PSU		
		Conceptualization (Existing Conditions)		Criteria Design (Schematic)		Detail & Implementation Documentaion		Shop Drawings		Construction Adminstration		As-Built Model		Record Model		Notes
		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
A1010	**Standard Foundations**															
	Wall & Column Foundations	100	KT	200	CVM	300	CVM									
	Foundation Walls	100	KT	200	CVM	300	CVM									
	Grade Beams	100	KT	200	CVM	300	CVM									
	Pile Caps	TBD		200	CVM	300	CVM									
	Excavation, Backfill & Compaction	N/A	TBD	N/A		N/A										
	Footings & Bases	N/A	TBD	N/A		N/A										
	Perimeter Insulation	N/A	TBD	N/A		N/A										
	Perimeter Drainage	N/A	TBD	N/A		N/A										
	Anchor Plates/Bolt Patterns	-		-		-										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
A1020	**Special Foundations**															
	Pile Foundations	-		200	CVM	300	CVM									
	Grade Beams	TBD		TBD		TBD										
	Caissons	TBD		TBD		TBD										
	Underpinning	TBD		TBD		TBD										
	Dewatering	N/A		N/A		N/A										
	Raft Foundations	TBD		TBD		TBD										
	Pressure Injected Grouting	TBD		TBD		TBD										
	Other Special Conditions	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
A1030	**Slab in Grade**															
	Standard Slab on Grade	100	KT	200	CVM	300	CVM									
	Structural Slab on Grade	100	KT	200	CVM	300	CVM									
	Inclined Slab on Grade	100	KT	200	CVM	300	CVM									
	Trenches, Pits, and Bases	100	KT	100	CVM	300	CVM									
	Under-Slab Drainage and Insulation	TBD		TBD	TBD	TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
A2010	**Basement Excavation**															
	Excavation for Basements		TBD													
	Structure Back Fill and Compaction		TBD													
	Shoring		TBD													
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
A2020	**Basement Walls**															
	Basement Wall Construction	TBD		TBD		TBD										
	Moisture Protection	N/A		N/A		N/A										
	Basement Wall Insulation	N/A		N/A		N/A										
	Interior Skin	100	KT	200	KT	300	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards	N/A		N/A		N/A										
B1010	**Floor Construction**															
	Suspended Basement Floors Construction	TBD		TBD		TBD										
	Upper Floors Construction	100	KT	200	CVM	300	CVM									
	Balcony Floors Construction	100	KT	200	CVM	300	CVM									
	Ramps	100	KT	200	CVM	300	CVM									
	Exterior Stairs and Fire Escapes	100	KT	200	CVM/ KT	300	CVM/ KT									
	Floor Raceway Systems	TBD		TBD		TBD										
	Equipment Pads	-		200	CVM	300	CVM									
	Other Floor Construction	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
B1020	**Roof Construction**															
	Roof Construction	100	KT	200	CVM/ KT	300	CVM/ KT									
	Canopies	TBD		TBD		TBD										
	Other Roof Systems	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
B2010	**Exterior Walls**															
	Exterior Structural Wall Construction	100	KT	200	CVM	300	CVM									
	Exterior Non-Structural Wall Construction	100	KT	200	KT	300	KT									
	Parapets	100	KT	200	CVM	300	CVM									
	Exterior Louvers, Screens, and Facing	100	KT	200	KT	300	KT									
	Exterior Sun Control Devices	100	KT	200	KT	300	KT									
	Structural Support for Louvers/ Sun Control Devices	-		-		300	CVM									
	Balcony Walls and Handrails	TBD		TBD		TBD										
	Exterior Soffits	100	KT	200	KT	300	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
B2020	**Exterior Windows**															
	Windows	100	KT	200	KT	300	KT									
	Curtain Walls	100	KT	200	KT	300	KT									
	Storefronts	100	KT	200	KT	300	KT									
	Structural Support for Opening/ Reinforcement	-		200	CVM	300	CVM									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
B2030	**Exterior Doors**															

		Design Intent Model						Means and Methods Model						Integration with PSU		
		Conceptualization (Existing Conditions)		Criteria Design (Schematic)		Detail & Implementation Documentaion		Shop Drawings		Construction Adminstration		As-Built Model		Record Model		Notes
		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
	Glazed Doors and Entrances	200	KT	200	KT	300	KT									
	Solid Exterior Doors	200	KT	200	KT	300	KT									
	Revolving Doors	TBD		TBD		TBD										
	Overhead Doors	200	KT	200	KT	300	KT									
	Personnel Doors	200	KT	200	KT	300	KT									
	Other Doors and Entrances	TBD		TBD		TBD										
	Structural Support for Opening/ Reinforcement	-		200	CVM	300	CVM									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
B3010	**Roof Coverings**															
	Roof Finishes			200	KT	300	KT									
	Traffic Toppings and Paving Membranes			200	KT	300	KT									
	Roof Insulation and Fill			200	KT	300	KT									
	Flashings and Trim			200	KT	300	KT									
	Copings			200	KT	300	KT									
	Roof Eaves and Soffits			200	KT	300	KT									
	Gutters and Downspouts			200	KT	300	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)															
B3020	**Roof Openings**															
	Skylights and Glazing			200	KT	300	KT									
	Roof Hatches			200	KT	300	KT									
	Vents			200	KT	300	KT									
	Structural Support/ Reinforcing for Roof Openings	-		200	CVM	300	CVM									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
C1010	**Interior Walls**															
	Fixed Partitions	100	KT	200	KT	300	KT									
	Interior Structural Walls	-		200	CVM	300	CVM									
	Demountable Partitions	100	KT	200	KT	300	KT									
	Structural Support for Partitions (Demountable/ Retractable)	-		-		300	CVM									
	Retractable Partitions	100	KT	200	KT	300	KT									
	Toilet Partitions	-		200	KT	300	KT									
	Cubicle Walls (?Systems Furniture)	TBD		200	KT	TBD	KT									
	Interior Balustrades and Screens	-		200	KT	300	KT									
	Interior Windows and Storefronts	100	KT	200	KT	300	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
C1020	**Interior Doors**															
	Interior Doors	100	KT	200	KT	300	KT									
	Interior Door Frames			200	KT	300	KT									
	Interior Door Hardware			200	KT	300	KT									
	Interior Door Wall Opening Elements			200	KT	300	KT									
	Interior Door Sidelights and Transoms			200	KT	300	KT									
	Interior Hatch and Access Doors			200	KT	300	KT									
	Door Painting and Decoration					050										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
C1030	**Fittings**															
	Fabricated Toilet Partitions			200	KT	300	KT									
	Fabricated Compartments and Cubicles			200	KT	300	KT									
	Storage Shelving and Lockers			200	KT	300	KT									
	Ornamental Metals and Handrails			200	KT	300	KT									
	Identifying Devices					050										
	Closet Specialties					050										
	General Fittings and Misc. Metals					050										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
C2010	**Stair Construction**															
	Stair Treads, Risers, & Landings	100	KT	200	CVM/ KT	300	CVM/ KT									
	Stair Handrails and Balustrades	-		200	KT	300	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
C2020	**Stair Finishes**															
	Stair, Tread, Landing Finishes			200	KT	300	KT									
	Stair Soffit Finishes			200	KT	300	KT									
	Stair Handrail and Balustrade Finishes					050	KT									
C3010	**Wall Finishes**															
	Wall Finishes to Inside Exterior Walls			200	KT	300	KT									
	Wall Finishes to Inside Walls			200	KT	300	KT									
	Column Finishes			200	KT	300	KT									
	Other															
C3020	**Floor Finishes**															
	Floor Toppings			200	KT	300	KT									
	Traffic Membranes					050	KT									
	Hardeners and Sealers					050	KT									
	Flooring			200	KT	300	KT									
	Carpeting			200	KT	300	KT									
	Bases, Curbs, Trim			200	KT	300	KT									

		Design Intent Model						Means and Methods Model						Integration with PSU		
		Conceptualization (Existing Conditions)		Criteria Design (Schematic)		Detail & Implementation Documentaion		Shop Drawings		Construction Adminstration		As-Built Model		Record Model		Notes
		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
	Access Pedastal Flooring			200	KT	300	KT									
	Other															
C3030	**Ceiling Finishes**															
	Ceiling Finishes			200	KT	300	KT									
	Suspended Ceilings			200	KT	300	KT									
	Trim and Decoration					300	KT									
	Other Ceilings															
D1010	**Elevators & Lifts**															
	Passenger Elevators	100	KT	200	KT	300	KT									
	Elevator Shafts/ Rails/ Hoist Beams	100	KT	100	CVM	300	CVM									
	Freight Elevators			TBD												
	People Lifts			TBD												
	Wheelchair Lifts			TBD												
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D1020	**Escalators & Moving Walks**															
	Escalators															
	Moving Walks															
	Means & Methods (Erection/Sequencing/ Shop Standards)															
D1030	**Other Conveying Systems**															
	Dumbwaiters															
	Pneumatic Tube Systems															
	Hoists and Cranes	TBD		TBD		TBD										
	Structural Support for Hoists/ Cranes	TBD		TBD		TBD										
	Conveyors															
	Chutes															
	Turntables															
	Baggage Handling and Loading Systems															
	Transportation Systems															
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D2010	**Plumbing Fixtures**															
	Water Closets	100	KT	200	KT	200	KT									
	Urinals	100	KT	200	KT	200	KT									
	Lavatories	100	KT	200	KT	200	KT									
	Sinks	100	KT	200	KT	200	KT									
	Bathtubs	100	KT	200	KT	200	KT									
	Wash Fountains	100	KT	200	KT	200	KT									
	Showers	100	KT	200	KT	200	KT									
	Drinking Fountains and Coolers	100	KT	200	KT	200	KT									
	Bidets and Other Plumbing Fixtures	100	KT	200	KT	200	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D2010	**Domestic Water Distribution**															
	Cold Water Service	-		200	BBA	300	BBA									
	Hot Water Service	-		200	BBA	300	BBA									
	Pipes & Fittings	-		-	BBA	300	BBA									
	Valves, Hydrants, & Hose Bibbs	-		-	BBA	300	BBA									
	Water Heater	-		200	BBA	300	BBA									
	Domestic Water Supply Equipment	-		200	BBA	300	BBA									
	Insulation	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D2030	**Sanitary Waste**															
	Waste Piping & Fittings	-		-		300	BBA									
	Vent Piping & Fittings	-		-		300	BBA									
	Floor Drains	-		200	BBA	300	BBA									
	Sanitary Waste Equipment	-		200	BBA	300	BBA									
	Pipe Insulation	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D2040	**Rain Water Drainage**															
	Pipe and Fittings	-		-		300	BBA									
	Roof Drains	-		200	BBA	300	BBA									
	Cistern	-		200	BBA	300	BBA									
	Filtration	-		200	BBA	300	BBA									
	Other Rainwater Drainage Equipment	-		200	BBA	300	BBA									
	Pipe Insulation	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D2090	**Other Plumbing Systems**															
	Gas Distribution	N/A		N/A		N/A										
	Acid Waste Systems	N/A		N/A		N/A										
	Interceptors	N/A		N/A		N/A										
	Pool Piping and Equipment	N/A		N/A		N/A										
	Decorative Fountain Piping Devices	N/A		N/A		N/A										
	Other Piping Systems	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										

		Design Intent Model						Means and Methods Model						Integration with PSU		
		Conceptualization (Existing Conditions)		Criteria Design (Schematic)		Detail & Implementation Documentaion		Shop Drawings		Construction Adminstration		As-Built Model		Record Model		Notes
		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
D3010	**Energy Supply**															
	Oil Supply System	N/A		N/A		N/A										
	Gas Supply System	-		200	BBA	300	BBA									
	Coal Supply System	N/A		N/A		N/A										
	Steam Supply System	N/A		N/A		N/A										
	Hot Water Supply System	-		200	BBA	300	BBA									
	Solar Energy System	-		200	BBA	300	BBA									
	Wind Energy System	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D3020	**Heat Generating Systems**															
	Boilers			200	BBA	300	BBA									
	Boiler Room Piping and Specialties	-		-		300	BBA									
	Auxilary Equipment	-		200	BBA	300	BBA									
	Insulation	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D3030	**Cooling Generating Systems**															
	Chillers	-		200	BBA	300	BBA									
	Cooling Towers and Evaporative Coolers	-		200	BBA	300	BBA									
	Condensing Units	-		200	BBA	300	BBA									
	Pipes & Fittings	-		-		300	BBA									
	Primary Pumps	-		200	BBA	300	BBA									
	Auxillary Equipment	-		200	BBA	300	BBA									
	Insulation	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D3040	**Distribution Systems**															
	Supply & Return Air Systems	-		200	BBA	300	BBA									
	AHU w/coils, ducts, and devices	-		200	BBA	300	BBA									
	Vent & Exhaust Systems	-		-		300	BBA									
	Steam, Hydronic, Hot Water, Glycol & Chilled Water Distribution	-		-		300	BBA									
	Heat Recovery Equipment	-		200	BBA	300	BBA									
	Auxillary Equipment	-		200	BBA	300	BBA									
	Insulation	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D30'050	**Terminal & Package Units**															
	Terminal Self-Contained Units	-		200	BBA	300	BBA									
	Package Units	-		200	BBA	300	BBA									
	Other	-		TBD												
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D3060	**Controls & Instrumentation**															
	Heating Generating Systems	-		-		300	BBA									
	Cooling Generating Systems	-		-		300	BBA									
	Heating/Cooling Air Handling Units	-		-		300	BBA									
	Exhausts and Ventilating Systems	-		-		300	BBA									
	Hoods and Exhaust Systems	-		-		300	BBA									
	Terminal Devices	-		-		300	BBA									
	Energy Monitoring and Control	-		-		300	BBA									
	Building Automation Systems	-		-		300	BBA									
	Other Controls and Instrumentation	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D3070	**Systems Testing & Balancing**															
	Commissioing Cx	? TBD		?		? TBD										
D3090	**Other HVAC Systems & Equipment**															
	Special Cooling Systems and Devices	-		TBD		TBD										
	Structural Support for HVAC Systems	-		200	CVM	300	CVM									
	Special Humidity Control	-		-		300	BBA									
	Dust and Fume Collectors	-		TBD		TBD										
	Air Curtains	-		TBD		TBD										
	Air Purifiers	-		TBD		TBD										
	Paint Spray Booth Ventilation	-		TBD		TBD										
	General Construction Items (HVAC) (?Hangers and supports0	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D4010	**Sprinklers**															
	Sprinkler Water Supply	-		-		300	BBA									
	Sprinkler Pumping Equipment	-		200	BBA	300	BBA									
	Sprinkler Heads	-		200	BBA	300	BBA									
	Dry Sprinkler System	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D4020	**Standpipes**															
	Standpipe Water Supply	N/A		N/A		N/A										
	Pumping Equipment	N/A		N/A		N/A										
	Standpipe Equipment	N/A		N/A		N/A										
	Fire Hose Equipment	N/A		N/A		N/A										

		Design Intent Model						Means and Methods Model						Integration with PSU		
		Conceptualization (Existing Conditions)		Criteria Design (Schematic)		Detail & Implementation Documentaion		Shop Drawings		Construction Adminstration		As-Built Model		Record Model		Notes
		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D4030	**Fire Protection Specialties**															
	Fire Extinguishers	N/A		N/A		N/A										
	Fire Extinguisher Cabinets	-		200	KT	300	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D4090	**Other Fire Protection Systems**															
	Carbon Dioxide Systems	N/A		N/A		N/A										
	Ammonia Systems	N/A		N/A		N/A										
	Foam Generating Equipment	N/A		N/A		N/A										
	Clean Agent Systems	N/A		N/A		N/A										
	Dry Chemical System	N/A		N/A		N/A										
	Hood and Duct Fire Protection	N/A		N/A		N/A										
	Fire Alarm	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D'05010	**Electrical Service & Distribution**															
	Primary Transformers	-		200	BBA	300	BBA									
	Secondary Transformers	-		200	BBA	300	BBA									
	Main Switchboard	-		200	BBA	300	BBA									
	Interior Distribution Transformer	-		200	BBA	300	BBA									
	Branch Circuit Panels	-		-		300	BBA									
	Motor Control Center	-		200	BBA	300	BBA									
	Conduit & Wiring to Circuit Panels	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D'05020	**Lighting & Branch Wiring**															
	Lighting Fixtures	-		200	KT/ A10	300	KT/ A10									
	Devices	-		-		300	BBA									
	Exterior Building Lighting	-		100	KT/ A10	300	KT/ A10									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D'05030	**Communication and Security**															
	Fire Alarm System	-		-		300	BBA									
	Intercom System	-		-		300	BBA									
	Tele-Data System	-		-		300	BBA									
	Access Control	-		-		300	BBA									
	Panic-Emergency Call Devices	-		-		300	BBA									
	Security Syste,/Cameras	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
D'05090	**Other Electrical Systems**															
	Grounding Systems	-		-		300	BBA									
	Emergency Light and Power Systems	-		100	KT/ A10	300	BBA									
	Floor Raceway Systems	-		TBD		TBD										
	Other Special Systems and Devices	-		TBD		TBD										
	General Construction Items (Elect)	-		-		300	BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
E1010	**Commercial Equipment**															
	Security and Vault Equipment															
	Teller and Service Equipment															
	Registration Equipment															
	Checkroom Equipment															
	Mercantile Equipment															
	Laundry and Dry Cleaning Equipment															
	Vending Equipment			200	KT	200	KT									
	Office Equipment			200	KT	200	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
E1020	**Institutional Equipment**															
	Ecclesiastical Equipment															
	Library Equipment															
	Theater and Stage Equipment					TBD										
	Instrumental Equipment															
	Audio-visual Equipment	-		-		TBD	(FFE/AV)									
	Detention Equipment															
	Laboratory Equipment	-		-												
	Medical Equipment															
	Other Instrumentational Equipment															
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
E1030	**Vehicular Equipment**															
	Vehicular Service Equipment					TBD										
	Parking Control Equipment					TBD										
	Loading dock Equipment	-		-		300	CVM									
	Other Vehicular Equipment															
E1090	**Other Equipment**															
	Maintenance Equipment															
	Solid Waste Handling Equipment															

		Design Intent Model						Means and Methods Model						Integration with PSU		
		Conceptualization (Existing Conditions)		Criteria Design (Schematic)		Detail & Implementation Documentaion		Shop Drawings		Construction Adminstration		As-Built Model		Record Model		Notes
		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
	Food Service Equipment	100	KT	200	KT	300	KT									
	Residential Equipment															
	Unit Kitchens															
	Window Washing equipment															
	Other Equipment															
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
E2010	**Fixed Furnishings**															
	Fixed Artwork					TBD										
	Fixed Casework			200	KT	300	KT									
	Blinds and Other Window Treatment			200	KT	300	KT									
	Fixed Floor Grilles and Mats			200	KT	300	KT									
	Fixed Multiple Seating			200	KT	300	KT									
	Fixed Interior Landscaping					TBD										
	Other															
E2020	**Movable Furnishings**															
	Movable Artwork					TBD										
	Furniture and Accessories / Fitness Equipment					TBD										
	Movable Rugs and Mats					TBD										
	C A !e Interior Lan#scaping					TBD										
	Other															
F1010	**Special Structure**															
	Air Supported Structures															
	Pre-engineered Structures															
	Other Special Structures															
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
F1020	**Integrated Construction**															
	Integrated Assemblies															
	Special Purpose Rooms															
	Clean Rooms															
	Other Integrated Construction															
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
F1030	**Special Construction Systems**															
	Sound, Vibration, Seismic Const.			0'050		-										
	Radiation Protection															
	Special Security Systems															
	Vaults															
	Other Special Construction Systems															
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
F1040	**Systems for Special Facilities**															
	Aquatic Facilities															
	Ice Rinks															
	Site Constructed Incinerators															
	Kennels and Animal Shelters															
	Liquid Gas and Storage Tanks															
	Other Special Facilities															
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
F10'050	**Special Controls & Instrumentation**															
	Recording Instrumentation					TBD										
	Building Automation Systems					TBD										
	Other Special Controls and Instrum. (monitoring sensors)					300	KT									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
F2010	**Building Elements Demolition**															
	Building Elements Demolition	200	KT	300	KT											
	Hazardous Components Abatement	N/A		N/A												
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		400	?									
G1010	**Site Clearing**															
	Site Clearing	200	H	300	H											
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A												
G1020	**Site Demolition & Relocations**															
	Site Demolition	200	H	300	H	300	H									
	Relocation of Building Utilities	200	H	300	H	400	H									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G1030	**Site Earthwork**															
	Shoring Walls															
	Site/Topography	300	H	300	H	300	H									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G1040	**Hazardous Waste Remediation**															
	Waste Remediation	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G2010	**Roadways**															
	Paving & Surface	100	KT	200	H	300	H									
	Curbs & Gutters	100	KT	200	H	300	H									

		Design Intent Model						Means and Methods Model						Integration with PSU		
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		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
	Rails & Barriers	N/A		N/A		N/A										
	Markings & Signage	N/A		200	H	200	H									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G2020	**Parking Lots**															
	Parking Lot Paving	TBD		TBD		TBD										
	Curbs, Rails, & Barriers	TBD		TBD		TBD										
	Parking Booths & Equipment	TBD		TBD		TBD										
	Markings & Signage	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G2030	**Pedestrian Paving**															
	Pavers & Walkways	200	KT	200	H	300	H									
	Exterior Steps/ Ramps	100	KT	200	H/ CVM	300	H/ CVM									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G2040	**Site Devlopment**															
	Fences & Gates	N/A		N/A		N/A										
	Retaining Walls	TBD	H/ CVM/ BH	TBD	H/ CVM/ BH	TBD	H/ CVM/ BH									
	Terrace & Perimeter Walls	TBD	H/ CVM/ BH	TBD	H/ CVM/ BH	TBD	H/ CVM/ BH									
	Signage	TBD		TBD		TBD										
	Fountains & Pools	TBD		TBD												
	Playing Fields	N/A		N/A		N/A										
	Flag Poles	TBD		TBD		TBD										
	Other	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G20'050	**Landscaping**															
	Trees & Bushes	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G3010	**Water Supply & Distribution Systems**															
	Potable & Nonpotable Water Systems	100	H	200	H	300	H									
	Pumping Stations	N/A		N/A		N/A										
	Water Storage	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G3020	**Sanitary Sewer Systems**															
	Piping	100		200		300										
	Manholes	100		200		300										
	Septic Tanks	N/A		N/A		N/A										
	Catch Basins	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G3030	**Storm Sewer Systems**															
	Piping	100		200		300										
	Manholes	100		200		300										
	Catch Basins	100		200		300										
	Retention Ponds	TBD		TBD		TBD										
	Storm water management	100		200		300										
	Ditches & Culverts	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G3040	**Heating Distribution**															
	Steam Supply System	N/A		N/A		N/A										
	Condensation Return	N/A		N/A		N/A										
	Hot Water Supply System	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G30'050	**Cooling Distribution**															
	Chilled Water Piping	N/A		N/A		N/A										
	Pumping Stations	N/A		N/A		N/A										
	Cooling Towers on Site	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G3060	**Fuel Distribution**															
	Piping	100	H	200	H	300	H									
	Equipment	100	H	200	H	300	H									
	Storage Tanks	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G3090	**Other Civil/Mechanical Utilities**															
	Industrial Waste Systems	N/A		N/A		N/A										
	Petroleum & Lubricant Distribution System	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G4010	**Electrical Distribution**															
	Substations	TBD		TBD		TBD										
	Overhead & Underground Power Distribution	100	H/ BBA	200	H/ BBA	300	H/ BBA									
	Duct Banks	100	H/ BBA	200	H/ BBA	300	H/ BBA									
	Other (Generators/ Charging station)	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G4020	**Site Lighting**															
	Fixtures & Transformers	100	A10/ BBA	200	A10/ BBA	300	A10/ BBA									

		Design Intent Model						Means and Methods Model						Integration with PSU		
		Conceptualization (Existing Conditions)		Criteria Design (Schematic)		Detail & Implementation Documentaion		Shop Drawings		Construction Adminstration		As-Built Model		Record Model		Notes
		LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
	Poles	TBD		TBD		TBD										
	Conduit & Duct Banks	100	H/ BBA	200	H/ BBA	300	H/ BBA									
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G4030	**Site Communications & Security**															
	Communications	100	H/ BBA	200	H/ BBA	300	H/ BBA									
	Site Security	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G4090	**Other Electrical Utilities**															
	Special Electrical Utilities	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G'05010	**Service Tunnels**															
	Conduit & Duct Banks	N/A		N/A		N/A										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
G'05090	**Other Site Systems & Equipment**															
	Equipment	TBD		TBD		TBD										
	Means & Methods (Erection/Sequencing/ Shop Standards)	N/A		N/A		N/A										
	Designated Design/Performance Specifications															
	This section takes precedence over representations above in case there is duplication,															
	Design Construction/ Performance Specifications															
	This section takes precedence over representations above in case there is duplication,															
1	**Construction Systems**															
	Construction Equipment															
	Temporary Safety															
	Temporary Security															
	Temporary Facilities															
	Weather Protection															
2	**Space**															
	Construction Activity Space															
	Analysis Space															
3	**Information**															
	Construction Information															
	Engineering Information															
	Record Information															
	Additional															
	ALL EXISTING CONDITIONS TO BE MODELED TO A 200 LEVEL UNLESS DIRECTLY AFFECTED BY NEW CONSTRUCTION. THEN MODELED/DETAILED TO A 300 LEVEL TO ALLOW FOR DEMOLITION DRAWINGS AND TIE IN INFORMATION															

The following file documents the facility asset requirements for all projects at PSU.

Information for the items documents in this file are to be provided to Penn State in the method described in the BIM plan. At a minimum, each asset is to include listed parameters, a barcode, and the following:

O&M manual
Installation Guide
Submittal Information
Warranty Documentation
Commissioning Report
Any additional Documentation

It is the Professionals responsibility to provide design intent/ basis of design information as defined in the following pages.

It is the Contractors/ Prime Contractors responsibility to provide construction information as defined on the following pages and to verify the design information and acquire Maximo barcodes from PSU to place on all installed equipment. If the constructed information does not match the design intent information, a description must be given to explain the discrepancy.

It is the Commissioning Agent's responsibility to verify the existing information and provide the additional information as specified.

For any questions please contact Eric Nulton @ eric.nulton@psu.edu

Asset Information organized according to PSU UNIFORMAT II Standard

Asset	Parameter	Attribute	Responsibilities per Phase		
			Design	Construction	Commissioning

D 10 Conveying

Asset	Parameter	Attribute	Design	Construction	Commissioning
Elevator	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Cable) Dual Ropes Hy"rauli!)C* "rauli!) Holeless Hy"rauli!	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Capacity	# People	Recor"	Recor"	#ali"ate
	Elevator Lan"in.9	,	Recor"	#ali"ate	#ali"ate
	Elevator Maximum Load	-F	Recor"	Recor"	#ali"ate
	Elevator Spee"	F2D	Recor"	Recor"	#ali"ate
	Elevator T*pe (Select)	2assen. er) Frei. 3t	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Serial Number		/	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate
C ist	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Manual) Electri!	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Capacity	+on	Recor"	Recor"	#ali"ate
	C ist Hei. 3t	Feet	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Serial Number		/	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate

D2010 Plumbing Fixtures

Asset	Parameter	Attribute	Design	Construction	Commissioning
5 ater Fountain	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Refri. erate") Bottle Fillin. Station	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	ḱear Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Serial #		/	Recor"	#ali"ate

D2020 Domestic Water Distribution

Asset	Parameter	Attribute	Design	Construction	Commissioning
#alve	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	5 ater	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	Connection T*pe		Recor"	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Serial #		/	Recor"	#ali"ate
	#alve Style	Ball) Gate) Butterfl*) Che!6	Recor"	Recor"	#ali"ate
2ump	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Domestic Col" Water) Domestic Hot Water	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	Flui" Flowrate	82D	Recor"	#ali"ate	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	D asure" Driver MotorB mperageA23aseB	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23aseF	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23ase C	Bmp	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseB	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseF	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3ase C	#olt	/	/	Recor"
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	ḱumber of P3ase9	,	Recor"	#ali"ate	#ali"ate
	ḱominal Voltage	#olt	Recor"	#ali"ate	#ali"ate
	2ump RPD	RPD	Recor"	#ali"ate	#ali"ate
	Serial #		/	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate
	Space Serve"	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	+otal Head Pressure	Feet	Recor"	Recor"	Recor"

D2030 Sanitary Waste

Asset	Parameter	Attribute	Design	Construction	Commissioning
2ump	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Sewage	Recor"	#ali"ate	#ali"ate

	Maximo Barco"e #	,	/	Recor"	#ali"ate
	Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	D asure" Driver MotorB mperageA23aseB	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23aseF	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23ase C	Bmp	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseB	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseF	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3ase C	#olt	/	/	Recor"
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	ḱominal Voltage	#olt	Recor"	#ali"ate	#ali"ate
	ḱumber of P3ase⁹	,	Recor"	Recor"	Recor"
	Serial #		/	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate
	Space Serve"	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	⁺otal Head Pressure	Feet	Recor"	Recor"	Recor"

D30 HVAC

D3010 Energy Supply

Steam Trap	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	⁺3ermo) Bu!6et, F9⁺) Di%	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	2ipe Size	In!3	Recor"	#ali"ate	#ali"ate
	Serial #		/	Recor"	#ali"ate
	Steam Service Presssure	2SIG	Recor"	Recor"	Recor"
	Steam TrapB pplication	Radiator) Drip) Proce%%)Heat E+!3an. er) Coil) Still	Recor"	#ali"ate	#ali"ate
	⁺rapman ID Number		Recor"	#ali"ate	#ali"ate

Man3ole	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Electri!	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #	,	/	Recor"	#ali"ate

Man3ole	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Steam	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #	,	/	Recor"	#ali"ate
	Qty/Con"ensate Return Joints	,	Recor"	Recor"	#ali"ate
	Qty/Con"ensate Return Valve⁹	,	Recor"	Recor"	#ali"ate
	Qty/of Air S*stem Valve⁹	,	Recor"	Recor"	#ali"ate
	Qty/of HPS Expansion Joints	,	Recor"	Recor"	#ali"ate
	Qty/of HPS Steam Valve⁹	,	Recor"	Recor"	#ali"ate
	Qty/of L2S Expansion Joints	,	Recor"	Recor"	#ali"ate
	Qty/of L2S Steam Valve⁹	,	Recor"	Recor"	#ali"ate
	Qty/of Steam S*st Strainer⁹	,	Recor"	Recor"	#ali"ate
	Qty/of Steam Trap⁹	,	Recor"	Recor"	#ali"ate

D3020 Heat Generating Systems

Close" Loop	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	C t Water	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	#	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	2ercent/T*pe Gl*col	>	Recor"	Recor"	#ali"ate
	S*stem Volume	B -	Recor"	Recor"	#ali"ate
	⁺*pe Gl*col	Eth*lene Gl*col) NB	Recor"	#ali"ate	#ali"ate
	5 ater Loop Number	,	Recor"	#ali"ate	#ali"ate

F iler	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Cast Iron) Water Tu$e) Hot Water) Steam, Fire Tu$e)	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	F iler Size	F U/HR	Recor"	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Fuel T*pe		Recor"	#ali"ate	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	Maximum Wor6in. Pressure	2SIG	Recor"	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	ḱational Boar" Number		/	Recor"	Recor"
	Safety Relief Pressure	2SIG	Recor"	Recor"	#ali"ate
	Serial #	2SIG	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name		Recor"	#ali"ate

	++*pe	C t Water) Steam	Recor"	#ali"ate	#ali"ate
2ump	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Sump Pump	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	A	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	Manufacturer		Recor"	Recor"	#ali"ate
	D "el #		A	Recor"	#ali"ate
	D asure" Driver MotorB mperageA23aseB	Bmp	A	A	Recor"
	D asure" Driver MotorB mperageA23aseF	Bmp	A	A	Recor"
	D asure" Driver MotorB mperageA23ase C	Bmp	A	A	Recor"
	D asure" Driver Motor Voltage - P3aseB	#olt	A	A	Recor"
	D asure" Driver Motor Voltage - P3aseF	#olt	A	A	Recor"
	D asure" Driver Motor Voltage - P3ase C	#olt	A	A	Recor"
	Installation Date	DateDD)) 4444(	A	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	A	Recor"	#ali"ate
	Ḱominal Voltage	#olt	Recor"	#ali"ate	#ali"ate
	Ḱumber of P3ase9	,	Recor"	#ali"ate	#ali"ate
	2ump Di%!3ar. e Pressure	2SIG	Recor"	Recor"	Recor"
	2ump RPD	RPD	Recor"	Recor"	Recor"
	2ump Suction Pressure	2SIG	Recor"	Recor"	Recor"
	Serial #		A	Recor"	#ali"ate
	Source Breaker Number'%	,	A	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	A	Recor"	#ali"ate
	Space Serve"	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	+otal Head Pressure	Feet	Recor"	Recor"	Recor"
C ater	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Unit Heater) Cabinet Heater) Domestic Water) Infare" Gas	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	A	Recor"	#ali"ate
	Fan RPD	RPD	Recor"	Recor"	Recor"
	Fan Total Static Pressure	IN H2O	Recor"	Recor"	Recor"
	Fuel T*pe		Recor"	#ali"ate	#ali"ate
	C atin. Coil Capacity	F U/HR	Recor"	Recor"	#ali"ate
	C atin. Coil T*pe		Recor"	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	A	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	A	Recor"	#ali"ate
	Manufacturer		A	Recor"	#ali"ate
	D "el #		A	Recor"	#ali"ate
	Ratin.		Recor"	Recor"	#ali"ate
	Source Breaker Number'%	,	A	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	A	Recor"	#ali"ate
	+otalB ir Flo7	CFD	Recor"	Recor"	Recor"

D3030 Cooling Generating Systems

Bir Con"itioner	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Bir Con"itioner Unit, Package Terminal	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	#	A	Recor"	#ali"ate
	Coolin. Coil Capacity	F U/HR	Recor"	Recor"	#ali"ate
	Fan RPD	RPD	Recor"	Recor"	#ali"ate
	Fan Total Static Pressure	IN H2O	Recor"	Recor"	Recor"
	C atin. Coil Capacity	F U/HR	Recor"	Recor"	#ali"ate
	C atin. Coil T*pe		Recor"	Recor"	#ali"ate
	Installation Date	DateDD)) 4444(	A	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	A	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Manufacturer		A	Recor"	#ali"ate
	D "el #		A	Recor"	#ali"ate
	Outsi"eB ir'D nimum)	CFD	Recor"	Recor"	Recor"
	Refri. erant T*pe		Recor"	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	A	Recor"	#ali"ate
	Source Breaker Number'%	Room # (bl". #-room e+/0000000-000X)	A	Recor"	#ali"ate
	Space Serve"	#	Recor"	#ali"ate	#ali"ate
	+otal Suppl*B ir Flo7	CFD	Recor"	Recor"	Recor"
Chiller	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Reciprocatin. , Scroll) Centrifu. al Compressor	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	#	A	Recor"	#ali"ate
	Chille" Water E5 +	De. ree F	Recor"	Recor"	Recor"
	Chille" Water Flo7	82 D	Recor"	Recor"	Recor"
	Chille" Water L5 +	De. ree F	Recor"	Recor"	Recor"
	Con"enser Water E5 +	De. ree F	Recor"	Recor"	Recor"
	Con"enser Water Flo7	82 D	Recor"	Recor"	Recor"
	Con"enser Water L5 +	De. ree F	Recor"	Recor"	Recor"
	Installation Date	DateDD)) 4444(	A	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	A	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Manufacturer		A	Recor"	#ali"ate
	D "el #		A	Recor"	#ali"ate
	Ḱominal Ton9	+on	Recor"	#ali"ate	#ali"ate
	Ḱominal Voltage	#olt	Recor"	#ali"ate	#ali"ate
	Refri. erant Char. e	-F	Recor"	Recor"	Recor"
	Refri. erant T*pe		Recor"	Recor"	#ali"ate
	Source Breaker Number'%	#	A	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	A	Recor"	#ali"ate
Close" Loop	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Chille" Water	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	#	A	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	A	Recor"	#ali"ate

	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali" ate
	2ercent Gl*col	>	Recor"	Recor"	#ali" ate
	S*stem Volume	B -	Recor"	Recor"	#ali" ate
	⁺*pe Gl*col	Eth*lene Gl*col) NB	Recor"	Recor"	#ali" ate
	5 ater Loop Number	#	Recor"	Recor"	#ali" ate

5 al6An Cooler	Equipment ID		Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	#	/	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali" ate
	Manufacturer		/	Recor"	#ali" ate
	D "el #		/	Recor"	#ali" ate

Coolin. Tower	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Chille" Water	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	#	/	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Desi. n Wet Bul$ Temperature	De. ree F	Recor"	#ali" ate	#ali" ate
	Enterin. Water Temperature	De. ree F	Recor"	Recor"	Recor"
	-eavin. Water Temperature	De. ree F	Recor"	Recor"	Recor"
	Installation Date	DateDD)) 4444(	/	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali" ate
	Manufacturer		/	Recor"	#ali" ate
	D "el #		/	Recor"	#ali" ate
	2rocess Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	2rocess Flui" Inlet Temp/	De. ree F	Recor"	Recor"	Recor"
	2rocess Flui" Outlet Temp/	De. ree F	Recor"	Recor"	Recor"
	Source Breaker Number'%	,	/	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali" ate
	Space Serve"	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate

De3umi" ifier	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Dessicant, Refri. erant	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	#	/	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali" ate
	Manufacturer		/	Recor"	#ali" ate
	D "el #		/	Recor"	#ali" ate
	ḱ ominal Voltage	#olt	Recor"	#ali" ate	#ali" ate
	Source Breaker Number'%	,	/	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali" ate

2ump	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Chille" Water	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	/	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	Manufacturer		/	Recor"	#ali" ate
	D asure" Driver MotorB mperageA23aseB	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23aseF	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23ase C	Bmp	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseB	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseF	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3ase C	#olt	/	/	Recor"
	D "el #		/	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali" ate
	ḱ ominal Voltage	#olt	Recor"	#ali" ate	#ali" ate
	ḱ umber of P3ase%	,	Recor"	#ali" ate	#ali" ate
	2ump Di%!3ar. e Pressure	2SIG	Recor"	Recor"	Recor"
	2ump RPD	RPD	Recor"	Recor"	Recor"
	2ump Suction Pressure	2SIG	Recor"	Recor"	Recor"
	Serial #		/	Recor"	#ali" ate
	Source Breaker Number'%	,	/	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali" ate
	Space Serve"	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	⁺otal Head Pressure	Feet	Recor"	Recor"	Recor"

Fan	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Bir Han" lin.) ReturnB ir) E+3aust, Heat & Vent, Fan Coil Unit	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	/	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Coolin. Coil Capacity	F U/HR	Recor"	Recor"	#ali" ate
	Coolin. Coil T*pe	Chille" Water) Dx	Recor"	Recor"	#ali" ate
	Driver Motor RPD	RPD	Recor"	Recor"	Recor"
	Fan Di%!3ar. e Pressure	IN H2O	Recor"	Recor"	Recor"
	Fan RPD	RPD	Recor"	Recor"	Recor"
	Fan Suction Pressure	IN H2O	Recor"	Recor"	Recor"
	Fan Total Static Pressure	IN H2O	Recor"	Recor"	Recor"
	C atin. Coil Capacity	F U/HR	Recor"	Recor"	Recor"
	C atin. Coil T*pe	C t Water) Steam, Electri!	Recor"	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali" ate
	D asure" Driver MotorB mperageA23aseB	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23aseF	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23ase C	Bmp	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseB	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseF	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3ase C	#olt	/	/	Recor"
	D xe" B ir Temperature	De. ree F	Recor"	Recor"	Recor"
	D xe" B ir Temperature Setpoint	De. ree F		#ali" ate	#ali" ate
	Manufacturer		/	Recor"	#ali" ate

	D "el #		/	Recor"	#ali"ate
	ḱominal Voltage	#olt	Recor"	#ali"ate	#ali"ate
	Outsi"eB ir'D nimum)	CFD	Recor"	Recor"	Recor"
	2re3eat Coil Capacity	F U/HR	Recor"	Recor"	Recor"
	2re3eat Coil T*pe		Recor"	Recor"	#ali"ate
	Refri. erant T*pe		Recor"	Recor"	#ali"ate
	ReturnB ir Flo7	BCFD	Recor"	Recor"	Recor"
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate
	Space Serve"	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Suppl*B ir Temperature	De. ree F	Recor"	Recor"	Recor"
	Suppl*B ir Temperature Setpt	De. ree F	Recor"	#ali"ate	#ali"ate
	S*stem Static Pressure Setpt	IN H2O	Recor"	#ali"ate	#ali"ate
	S*stem T*pe		Recor"	#ali"ate	#ali"ate
	*otal Suppl*B ir Flo7	CFD	Recor"	Recor"	Recor"

D3040 Distribution

Collector	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Dust	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	C rsepower	C	Recor"	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	RPD	RPD	Recor"	Recor"	Recor"
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate

Compressor	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Bir	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Bir Capacity Delivere"	BCFD	Recor"	Recor"	#ali"ate
	BSME Reciever Size		Recor"	Recor"	#ali"ate
	Capacity	Gal	Recor"	Recor"	#ali"ate
	Di%!3ar. e Pressure	2SIG	Recor"	Recor"	Recor"
	Gas Capacity Delivere"	BCFD	Recor"	Recor"	#ali"ate
	C rse Power	C	Recor"	Recor"	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Maximum Air Pressure	2SIG	Recor"	Recor"	#ali"ate
	Maximum Gas Pressure	2SIG	Recor"	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate

Dr*erAB ir	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Refri. erant, Desiccant	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Refri. erant T*pe		Recor"	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate

F ower	Equipment ID		Recor"	Recor"	Recor"
	F ower RPD	RPD	Recor"	Recor"	Recor"
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate
	*otalB ir Flo7	CFD	Recor"	Recor"	Recor"

Fan	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Bir Han"lin.) ReturnB ir) E+3aust, Heat & Vent, Fan Coil Unit	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Coolin. Coil Capacity	F U/HR	Recor"	Recor"	#ali"ate
	Coolin. Coil T*pe		Recor"	Recor"	#ali"ate
	Driver Motor RPD	RPD	Recor"	Recor"	Recor"
	Fan Di%!3ar. e Pressure	IN H2O	Recor"	Recor"	Recor"
	Fan RPD	RPD	Recor"	Recor"	Recor"
	Fan Suction Pressure	IN H2O	Recor"	Recor"	Recor"
	Fan Total Static Pressure	IN H2O	Recor"	Recor"	Recor"
	C atin. Coil Capacity	F U/HR	Recor"	Recor"	#ali"ate
	C atin. Coil T*pe		Recor"	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D asure" Driver MotorB mperageA23aseB	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23aseF	Bmp	/	/	Recor"
	D asure" Driver MotorB mperageA23ase C	Bmp	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseB	#olt	/	/	Recor"
	D asure" Driver Motor Voltage - P3aseF	#olt	/	/	Recor"

	D asure" Driver Motor Voltage - P3ase C	#olt	ł	ł	Recor"
	D xe" B ir Temperature	De. ree F	Recor"	Recor"	Recor"
	D xe" B ir Temperature Setpoint	De. ree F	Recor"	#ali" ate	#ali" ate
	Installation Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	ḱ ominal Voltage	#olt	Recor"	Recor"	#ali" ate
	Outsi" eB ir' D nimum)	CFD	Recor"	Recor"	Recor"
	2re3eat Coil Capacity	F U/HR	Recor"	Recor"	#ali" ate
	2re3eat Coil T*pe		Recor"	Recor"	#ali" ate
	Refri. erant T*pe		Recor"	Recor"	#ali" ate
	ReturnB ir Flo7	BCFD	Recor"	Recor"	Recor"
	Source Breaker Number'%	,	ł	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ł	Recor"	#ali" ate
	Space Serve"	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Suppl*B ir Temperature	De. ree F	Recor"	Recor"	Recor"
	Suppl*B ir Temperature Setpt	De. ree F	Recor"	#ali" ate	#ali" ate
	S*stem Static Pressure Setpt	IN H2O	Recor"	#ali" ate	#ali" ate
	*otal Suppl*B ir Flo7	CFD	Recor"	Recor"	Recor"

C at E+!3an. er	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Bir Coole"	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ł	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Enterin. B ir Temperature	De. ree F	Recor"	Recor"	Recor"
	Manufacturer		ł	Recor"	#ali" ate
	D "el #		ł	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	Source Breaker Number'%	,	ł	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ł	Recor"	#ali" ate
	Space Serve"	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	*otalB ir Flo7	CFD	Recor"	Recor"	Recor"
	*u$e Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	*u$e Si" e Inlet Temperature	De. ree F	Recor"	Recor"	Recor"
	*u$e Si" e Outlet Temperature	De. ree F	Recor"	Recor"	Recor"

C at E+!3an. er	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	2late & Frame	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ł	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Col" Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	Col" Si" e Inlet Temperature	De. ree F	Recor"	Recor"	Recor"
	Col" Si" e Outlet Temperature	De. ree F	Recor"	Recor"	Recor"
	C t Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	C t Si" e Inlet Temperature	De. ree F	Recor"	Recor"	Recor"
	Installation Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	C t Si" e Outlet Temperature	De. ree F	Recor"	Recor"	Recor"
	Manufacturer		ł	Recor"	#ali" ate
	D "el #		ł	Recor"	#ali" ate
	ḱ ational Boar" Number		ł	Recor"	#ali" ate

C at E+!3an. er	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	S3ell & Tu$e	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ł	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Installation Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	Manufacturer		ł	Recor"	#ali" ate
	D "el #		ł	Recor"	#ali" ate
	ḱ ational Boar" Number		ł	Recor"	#ali" ate
	S3ell Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	S3ell Si" e Inlet Temperature	De. ree F	Recor"	Recor"	Recor"
	S3ell Si" e Outlet Temperature	De. ree F	Recor"	Recor"	Recor"
	*u$e Flui" Flowrate	82 D	Recor"	Recor"	Recor"
	*u$e Si" e Inlet Temperature	De. ree F	Recor"	Recor"	Recor"
	*u$e Si" e Outlet Temperature	De. ree F	Recor"	Recor"	Recor"

5 ater Heater	Equipment ID		Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ł	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Installation Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	Manufacturer		ł	Recor"	#ali" ate
	D "el #		ł	Recor"	#ali" ate
	Source Breaker Number'%	,	ł	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ł	Recor"	#ali" ate

Furnace	Equipment ID		Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ł	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Fuel T*pe	ḱ atural Gas, Oil) Propane	Recor"	#ali" ate	#ali" ate
	C at Input Maximum	F U/HR	Recor"	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ł	Recor"	#ali" ate
	Manufacturer		ł	Recor"	#ali" ate
	D "el #		ł	Recor"	#ali" ate
	Source Breaker Number'%	,	ł	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ł	Recor"	#ali" ate

#B#	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Fan Powere") Stan" ar")	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ł	Recor"	#ali" ate
SeeFB S Tab for	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate

	Installation Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
B" "itional Information Requirements	Manufacturer		ƒ	Recor"	#ali" ate
	D "el #		ƒ	Recor"	#ali" ate
	Source Breaker Number'%	,	ƒ	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ƒ	Recor"	#ali" ate
	Space Serve"	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate

Sensor	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Gas, Fire Eye) pC Humi" ity) Temperature	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ƒ	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Chemical Material		Recor"	#ali" ate	#ali" ate
	Installation Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	Manufacturer		ƒ	Recor"	#ali" ate
	D "el #		ƒ	Recor"	#ali" ate
	Sensin. Ran. e		Recor"	Recor"	#ali" ate

D50 Electrical

D5010 Electrical Service and Distribution

2anel$oar"9	Equipment ID		Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ƒ	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	B/I.C.	Bmp	Recor"	Recor"	#ali" ate
	Bmperage	Bmp	Recor"	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	Manufacturer		ƒ	Recor"	#ali" ate
	D "el #		ƒ	Recor"	#ali" ate
	Source Breaker Number'%	,	ƒ	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ƒ	Recor"	#ali" ate
	#oltage	#olt	Recor"	#ali" ate	#ali" ate

*ransformer	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Oil) Dr* type	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ƒ	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	FuseB mperage	Bmp	Recor"	Recor"	#ali" ate
	Fuse Class	Class Letter	Recor"	Recor"	#ali" ate
	Impe" ance	Ů3m	Recor"	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	ǥ#B Ratin.	ǥ#B	Recor"	Recor"	#ali" ate
	Manufacturer		ƒ	Recor"	#ali" ate
	D "el #		ƒ	Recor"	#ali" ate
	ḱumber of P3ase9	,	Recor"	#ali" ate	#ali" ate
	Oil Capacity	Gal	Recor"	Recor"	#ali" ate
	2rimar* Voltage	#olt	Recor"	#ali" ate	#ali" ate
	Secon" ar* Voltage	#olt	Recor"	#ali" ate	#ali" ate
	Source Breaker Number'%	,	ƒ	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ƒ	Recor"	#ali" ate
	*emperature Rise	De. ree F	Recor"	Recor"	#ali" ate
	Unit Wei. 3t	-F	ƒ	Recor"	#ali" ate
	5 irin. Connection	Delta-W*e) Delta-Delta, W*eA *e) W*e-Delta	Recor"	Recor"	#ali" ate

D5020 Lighting and Branch Wiring

Fixture	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Street Li. 3t	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ƒ	Recor"	#ali" ate
	-ocation	Street, Intersection) Par6in. lot, Buil" in.	Recor"	#ali" ate	#ali" ate
	Ballast Voltage	#olt	Recor"	Recor"	#ali" ate
	-amp Style	D tal Hali" e)C2 S) CF-) LE) Flourescent	Recor"	Recor"	#ali" ate
	-amp Wattage	5 att	ƒ	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	Manufacturer		ƒ	Recor"	#ali" ate
	D "el #		ƒ	Recor"	#ali" ate
	Source Breaker Number'%	,	ƒ	Recor"	#ali" ate
	Source Power Panel Name	2anel Name	ƒ	Recor"	#ali" ate
	Street Li. 3t Fixture Number		ƒ	Recor"	#ali" ate
	Street Li. 3t Serie9		ƒ	Recor"	#ali" ate

Fixture	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	C . 3 bay) Low bay) Recesse") Downli. 3t, Surface Mounte") Pen" ant	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ƒ	Recor"	#ali" ate
	-ocation	Room # (bl" . #-room e+/0000000-000X)	Recor"	#ali" ate	#ali" ate
	Ballast Voltage	#olt	Recor"	Recor"	#ali" ate
	-amp Style	D tal Hali" e)C2 S) CF-) LE) Flourescent	Recor"	Recor"	#ali" ate
	-amp #	,	Recor"	Recor"	#ali" ate
	-amp Wattage	5 att	Recor"	Recor"	#ali" ate
	Installation Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	5 arranty Date	DateDD)) 4444(	ƒ	Recor"	#ali" ate
	Manufacturer		ƒ	Recor"	#ali" ate
	D "el #		ƒ	Recor"	#ali" ate
	D untin. Hei. 3t	Feet	Recor"	Recor"	#ali" ate
	#oltage	#olt	Recor"	#ali" ate	#ali" ate

Contactor	Equipment ID		Recor"	#ali" ate	#ali" ate
	Su$classification (Select)	Street Li. 3t	Recor"	#ali" ate	#ali" ate
	Maximo Barco" e #	,	ƒ	Recor"	#ali" ate

	-ocation	Room Number	Recor"	#ali"ate	#ali"ate
	-ocation of Source	F il"in. Name	Recor"	#ali"ate	#ali"ate
	F eaker Size Fee"in. Contactor	Bmp	Recor"	#ali"ate	#ali"ate
	CCS Id Number		/	Recor"	#ali"ate
	Contactor Coil Voltage	#olt	Recor"	Recor"	#ali"ate
	Contactor Size	Bmp	Recor"	Recor"	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D asure" B mperage P3aseB	Bmp	/	/	Recor"
	D asure" B mperage P3aseF	Bmp	/	/	Recor"
	D asure" B mperage P3ase C	Bmp	/	/	Recor"
	ḱumber of Fixtures Serve"	,	Recor"	#ali"ate	#ali"ate
	Output Voltage	#olt		#ali"ate	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate
	Street Li. 3t Series Name		Recor"	Recor"	#ali"ate

D5030 Communications and Security

Bccess	Equipment ID		Recor"	#ali"ate	#ali"ate
Control	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
2anel	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate

D5090 Other Electrical Systems

Generator	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Emer. en!*	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	F il"in. /Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	B⁺S Maximo ID		/	Recor"	#ali"ate
	En. ine Manufacturer		/	Recor"	#ali"ate
	En. ine Mo"el Number		/	Recor"	#ali"ate
	En. ine Serial Number		/	Recor"	#ali"ate
	Fuel Consumption'D as. Load(	82C	Recor"	Recor"	Recor"
	Fuel Consumption'Rate" Power(	82C	Recor"	Recor"	#ali"ate
	Fuel T*pe		Recor"	#ali"ate	#ali"ate
	Generator Fuel Tan6 Capacity	B -	Recor"	Recor"	#ali"ate
	Generator Fuel Tan6 Wor6in. Cap	B -	Recor"	Recor"	#ali"ate
	Generator Runtime (Meas. Load(	HOUR	Recor"	Recor"	Recor"
	Generator Runtime (Rate" Power(	HOUR	Recor"	Recor"	#ali"ate
	ƺiloA olt/Ampere୨	ƺ#B	Recor"	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	Recor"	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D asure" B mp Neut	Bmp	/	/	Recor"
	D asure" B mp P3B	Bmp	/	/	Recor"
	D asure" B mp P3F	Bmp	/	/	Recor"
	D asure" B mp P3 C	Bmp	/	/	Recor"
	D "el #		/	Recor"	#ali"ate
	ḱumber of P3ase୨	,	Recor"	#ali"ate	#ali"ate
	Output Voltage	#olt	Recor"	Recor"	#ali"ate
	Rate" Full Load Cur	Bmp	Recor"	Recor"	#ali"ate
	Rate" Power Output	ƺ5	Recor"	Recor"	#ali"ate

Switch	Equipment ID		Recor"	#ali"ate	#ali"ate
	Su$classification (Select)	Electrical Transfer	Recor"	#ali"ate	#ali"ate
	Maximo Barco"e #	,	/	Recor"	#ali"ate
	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Bmperage	Bmp	Recor"	Recor"	#ali"ate
	CCSB ""re%'		/	Recor"	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	ḱumber of P3ase୨	#	Recor"	#ali"ate	#ali"ate
	Output Voltage	#olt	Recor"	Recor"	#ali"ate
	S*stem	Emer. en!*) Stan"$*	/	Recor"	#ali"ate

Uninterruptable	Equipment ID		Recor"	#ali"ate	#ali"ate
2ower	Maximo Barco"e #	,	/	Recor"	#ali"ate
Suppl*	-ocation	Room # (bl". #-room e+/0000000-000X)	Recor"	#ali"ate	#ali"ate
	Installation Date	DateDD)) 4444(	/	Recor"	#ali"ate
	5 arranty Date	DateDD)) 4444(	/	Recor"	#ali"ate
	Manufacturer		/	Recor"	#ali"ate
	Max Power	ƺ5	Recor"	Recor"	#ali"ate
	D "el #		/	Recor"	#ali"ate
	ḱumber of P3ase୨	,	Recor"	#ali"ate	#ali"ate
	Source Breaker Number'%	,	/	Recor"	#ali"ate
	Source Power Panel Name	2anel Name	/	Recor"	#ali"ate
	#oltage	#olt	Recor"	#ali"ate	#ali"ate

Asset	Parameter	UOM	Notes

Room / Space

Room	Campḱs		
	ǥḱ AECADEF ame		
	Room Nḱmber		VerAfyFFAthF cott HorCFF"! 863.7978
	Room Name		VerAfyFFAthF cott HorCFF"! 863.7978
	StuCeDt Seats	&	
	Seats	&	
	RooF' ḱDA oD DescrAŰAoD	B assroom/Class LaboratorAes/FacuBtyF Office)*Abray)+Ű eDSŰeA B B ass *aboratorAes/GeDerB F se/ResearchF Office/Research.*aboratorAes/PḱbBAc Ser0AceF Office)1 CA DstrA 0eFA ce/DemoDstrA oD. B ADAcal)/ ḱbBF- se./ erforD ce/ GeDerB FD Cl 1 CA DAstrA 0eF ḱŰŰorF1 reas/AḱA BaryF D terŰrAseD tercoBeEAateF thBeAcs	
	1 rea S5ḱareF eet	' t^2	
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	1 ssets		

Asset	Parameter	UOM	Notes
FBS Contr "Pane"	Equipment ID		
	Manufacturer		
	D !e"#		
	Electrical Circuit #		
	Serial #		
	Upstream Pane"ID		
	Downstream Pane"ID		
	Ro m Name	Ro m #	' erify with Scott Hor! @ 814.863.010+
	CCSB ! ! re$$		
' B' Contr "er	Equipment ID		
	Manufacturer		
	D !e"#		
	' B' Contr "e! (Equipment ID)		
	Electrical Circuit #		
	Serial #		
	Ro m Name	Ro m #	' erify with Scott Hor! @ 814.863.010+
	CCSB ! ! ress - CM Value		
	CCSB ! ! ress - FF' alue		
FBS 2/3 Static Pressure Meter B ctual l cati n of meter to be sh wn in mo! e"3	Equipment ID		
	Manufacturer		
	D !e"#		
	CCSB ! ! re$$		
	Ro m Name	Ro m #	' erify with Scott Hor! @ 814.863.010+

Equipment ID	Subclassification (Select)	Maximo Barcode #	Location	Cooling Coil Capacity	Cooling Coil Type	Driver Motor RPM	Fan Discharge Pressure	Fan RPM	Fan Suction Pressure	Fan Total Static Pressure	Heating Coil Capacity	Heating Coil Type	Installation Date	Warranty Date	Measured Driver Motor Amperage- Phase A
BC 01	Bir Handling	101010101	DE	50,000	Chilled Water	1750	#	1750	#	#	120000	C t Water	12/1/2011	12/1/2014	20.14
BC 02	Bir Handling	101010102	DE	50,000	Chilled Water	1500	#	1750	#	#	120000	C t Water	12/#%2011	12/#%2014	20.01
BC E	Bir Handling	101010103	DE	60,000	Chilled Water	1500	#	1750	#	#	120000	C t Water	12/E 2011	12/E 2014	19.85
BC 04	Bir Handling	101010104	DE	50,000	Chilled Water	2000	1.5	1500	1.5	1.5	100000	C t Water	12/&%2011	12/&%2014	19.*
BC 05	Bir Handling	101010105	M101	75,000	Chilled Water	2000	1.5	1500	1.5	1.5	100000	C t Water	12/5/2011	12/5/2014	20.21
BC 06	Bir Handling	101010106	M101	75,000	Chilled Water	2000	1.5	1500	1.5	1.5	100000	C t Water	12/(%2011	12/(%2014	20.05
BC 07	Bir Handling	101010107	M101	50,000	Chilled Water	1750	#	1750	#	#	120000	C t Water	12/"%2011	12/"%2014	20.14
BC 08	Bir Handling	101010108	M101	60,000	Chilled Water	1750	#	1750	#	#	120000	C t Water	12/*%2011	12/*%2014	20.18
BC 09	Bir Handling	101010109	M101	50,000	Chilled Water	1750	#	1750	#	#	120000	C t Water	12/)%2011	12/)%2014	20.11

*he ab$, e example is intended to di0/lay a p$ssi+le meth$d of d$34menting asset in2$rmati$n'

*he e54i/ment in2$rmati$n d$es n$t re/resent a specific pr$6ect and sh$4ld n$t infl4ence specificati$n of e54i/ment in an1 way'

Measured Driver Motor Amperage- Phase B	Measured Driver Motor Amperage- Phase C	Measured Driver Motor Voltage - Phase A	Measured Driver Motor Voltage - Phase B	Measured Driver Motor Voltage - Phase C	Mixed Air Temperature	Mixed Air Temperature Setpoint	Manufacturer	Model #	Nominal Voltage
20.14	20.01	207.1	207.E	208.)	55.1	55	Greenhe39	D CF-15LA C-5	208
20.01	19.85	207.1	208.)	208.)	55.1	55	Greenhe39	D CF-15LA C-5	208
19.85	19.*	207.1	208.)	206.&	55.1	55	Greenhe39	D CF-15LA C-5	208
19.*	20.21	208.)	206.&	206.)	55.1	55	Greenhe39	D CF-15LA C-5	208
20.14	20.05	208.)	206.)	207.1	55.1	55	Greenhe39	D CF-15LA C-5	208
20.01	20.14	206.&	207.1	208.)	55.1	55	Greenhe39	D CF-15LA C-5	208
19.85	20.18	206.)	207.1	206.&	55.1	55	Greenhe39	D CF-15LA C-5	208
19.*	20.11	207.1	208.)	206.)	55.1	55	Greenhe39	D CF-15LA C-5	208
20.21	20.18	209.E	208.)	207.1	55.1	55	Greenhe39	D CF-15LA C-5	208

Outside Air(Minimum)	Preheat Coil Capacity	Preheat Coil Type	Refrigerant Type	Return Air Flow	Source Breaker Number(s)	Source Power Panel Name	Space Served	Supply Air Temperature	Supply Air Temperature Setpt	System Static Pressure Setpt	System Type	Total Supply Air Flow
400	60000	C t Water	;<	3600	1,E 5	=135	0001000-135b	55	55	#		4000
400	60000	C t Water	;<	3600	7,9,11	=135	0001000-138	55	55	#		4000
400	60000	C t Water	;<	3600	13,15,17	=135	0001000-137	55	55	#		4000
400	60000	C t Water	;<	3600	2,4,(	=135	0001000-140	55	55	1.5		4000
400	40000	C t Water	ḱ%B	3600	1,E 5	=101	0001000-101	55	55	1.5		4000
400	40000	C t Water	ḱ%B	3600	7,9,11	=101	0001000-105	55	55	1.5		4000
400	40000	C t Water	ḱ%B	3600	2,4,(	=101	0001000-116	55	55	#		4000
400	60000	C t Water	;<	3600	8,10,12	=101	0001000-178	55	55	#		4000
400	60000	C t Water	;<	3600	14,16,18	=101	0001000-195	55	55	#		4000

ATTACHMENT 4: PROCESS DEFINITION EXAMPLE

COORDINATION AND CONFLICT RESOLUTION

When conflicts are discovered in the model, regardless of project phase or LOD, the discovering party shall promptly notify the Model Element Author. Upon notification, the Model Element Author shall act promptly to mitigate the conflict. All project stakeholders and responsible parties must post their models to the designated shared server on a weekly basis as specified. Before the model(s) are shared and/or transferred, the model should be audited to conform to the following standards:

- Begin coordination process as early as possible
  - Designate the Project Model Manager
  - Designate BIM contact for each project stakeholder
  - Specify LOD for all Model Attributes
  - Create file storage and transfer process (workspace, model naming convention, model protocol)
  - Verify file type, compatibility, and needs
- Create schedule of expectations for model delivery
  - Deadlines for each project stakeholder based on level, area, phase
  - Set file upload dates (weekly) with time for interdisciplinary coordination
- Validate Model
  - Apply construction means and methods to architectural and structural model
  - Ensure model integrity and accuracy
- Establish conceptual placement of components within the architectural space
- Determine coordination hierarchy, for example:
  - Architectural
  - Structural
  - Equipment
  - HVAC Duct
  - Wet Mechanical
  - Gravity Plumbing
  - MEPF Risers
  - HVAC Distribution
  - Plumbing Distribution
  - Electrical Distribution
  - Fire Protection Distribution
- Clash Detection process
  - Project stakeholders access each other's models to work on specific level, area, phase
  - Clash resolution to be worked out among project stakeholders
  - BIM Model Manager will check models for interference and conflicts
  - BIM Model Manager will distribute composite model in .nwd format showing unresolved clashes and clash report document for project stakeholder review and resolution before next coordination meeting
  - Weekly coordination meetings will take place to address unresolved issues with the composite model
  - BIM Model Manager will distribute meeting minutes and resolution decisions after each meeting to project team
  - Process begins again to address the next level, area, phase
  - Clash-free model is then distributed to all parties and signed off as per project phase

Appendix C: 661 Roof Structure - Head House

Project: GPIC Building 661   Date: Aug 31, 2012   A3 No.______   Preparer: Amanda Goolsby   Collaborators: KT, CVM, BBA, Aramark, BB, A10

661 Roof Structure – Head House

BACKGROUND: The team evaluated the options for the roof structure – utilize a precast concrete plank or a Structural Insulated Panel (SIP). The team had previously determined that a precast plank similar to the existing ones is available.

CURRENT CONDITION: At the time of this evaluation the team planned to replace all damaged precast planks in kind and install the required insulation at the exterior across the entire area. This plan was the intent for both the high bay roof and the head house roof.

SUMMARY OF OPTIONS:

Replace Existing Planks (damaged only)

- About 4.75” + insulation (R30), so similar to the SIP thickness
- Risks:
  - Installing items at roof – Lighting, sprinkler, MEP, etc. – may cause more damage to the existing planks and create a need to replace more planks (after the initial removal and roofing have been completed)
  - Requires shoring where interior walls are removed
  - Existing Insulation is not reusable – removal of fully adhered insulation may cause further damage to panels
- Concerns with using spray foam insulation:
  - Perlins creating condensation
  - Schedule concerns due to restrictions in the space when it’s being applied
  - Expansion – it’s not clear if the plank turndowns could handle the lateral load caused by the foam
- Assessment of damage to planks
  - Can occur once ceilings are demo’d
  - Currently estimate damage on ~10% of planks
  - There’s indication water may be coming through joints
- Possible that repairs can be made to these planks in lieu of replacement due to limited damage and non-exposed ceilings
- Pros: Embodied Energy in planks, low first cost, damage to planks in head house appears much less than that observed in the high bay area
- Cons: Spalling risk/longevity (low risk), infiltration, thermal, load factor

Install new SIPs across entire Head House

- About 8.5” thick
- R30 Panel
- R60 Panel
  - Use would eliminate need for perimeter heating
- Pros: Energy performance, infiltration, thermal
- Cons: First cost

Use of precast planks would mean use of two different structural systems (head house vs. high bay)

- Pros: Learning opportunity
- Cons: Repeatability

	Learning	Influence			Collaborative Environments			Systems Integration	Repeatable Performance		Cost Certainty			Time Reliability		
661 Roof	Team Learning from Use	Integrated Processes	Job Growth / Creation	Economic Development	Indoor Air Quality	Functional Work Environment	Collaborative Work Environment	Energy Use Reduction through Integration	Scalable and Repeatable for Others	Non-proprietary Items	First Cost	Operating Cost (Utilities)	Operating Cost (Maintenance)	Minimize Construction Schedule Risk	Minimize Risk of Redesign	Notes
Weighting	3	2	2	2	2	2	1	3	2	2	3	3	3	2	2	
Structure																
Headhouse: Replace existing plank (damaged only)	+	0	0	0	0	0	0	0	+	-	+	0	0	-	0	if cracks are visible, will need to be replaced; will require shoring where interior walls are removed
Repair Damaged Planks - headhouse	+	0	0	0	0	0	0		+							
New SIP - headhouse	0	0	0	0	0	0	0	+	0	0	-	+	0	+	0	
Insulation / Air Barrier																
Headhouse: add ext rigid insulation outboard of planks																minimum target of R30 (5.5-6"). Existing insulation is not reusable.
Headhouse: Spray foam from the interior																using spray foam from interior for wall insulation. Concern about condensation at perlins due to break in insulation. Open or closed cell?

RECOMMENDATION:

The team determined the use of SIPs is not preferred for the head house. The decision of repair vs. replacement of the precast planks still needs to be made.

SIGNOFF (BSC members):

FOLLOW-UP:

CVM and KT to provide further feedback on preference of repair vs. replacement

Project Values Measurement

Affect on:			
Influence			
Repeatable Demonstration			
Learning			
Collaborative Environments			
Systems Integration			
Cost Certainty			
Time Reliability			

PENNSTATE 1855 GPICHUB KIERANTIMBERLAKE Balfour Beatty

Appendix D: 661 Roof Structure - High Bay

Project: GPIC Building 661 Date: Aug 31, 2012 A3 No._____ Preparer: Amanda Goolsby Collaborators: KT, CVM, BBA, Aramark, BB, A10

661 Roof Structure – High Bay

BACKGROUND: The team evaluated the options for the roof structure – utilize a precast concrete plank or a Structural Insulated Panel (SIP). The team had previously determined that a precast plank similar to the existing ones is available and that repairing the existing damaged planks is not preferred.

CURRENT CONDITION: At the time of this evaluation the team planned to replace all damaged precast planks in kind and install the required insulation at the exterior across the entire area. This plan was the intent for both the high bay roof and the head house roof.

SUMMARY OF OPTIONS:

Replace Existing Planks (damaged only)

- About 4.75" + insulation (R30), so similar to the SIP thickness
- Risks:
  - Installing items at roof – Lighting, sprinkler, MEP, etc. – may cause more damage to the existing planks and create a need to replace more planks (after the initial removal and roofing have been completed)
  - Requires shoring where interior walls are removed
  - Existing Insulation is not reusable – removal of fully adhered insulation may cause further damage to panels
  - Hairline cracks were observed during the Selective Demo work
- Concerns with using spray foam insulation:
  - Perlins creating condensation
  - Challenging detail - spray foam is interior at wall, exterior at roof
  - Schedule concerns due to restrictions in the space when it's being applied
  - Expansion – it's not clear if the plank turndowns could handle the lateral load caused by the foam
- Pros: Embodied Energy in planks, low first cost
- Cons: Spalling risk/longevity, infiltration, thermal, load factor

Install new SIPs across entire High Bay

- About 8.5" thick
- R30 Panel
- R60 Panel
  - Use would eliminate need for perimeter heating
- Pros: Energy performance, infiltration, thermal
- Cons: First cost
  - The first cost is less of a delta (vs precast) if more than 60% of the high bay area needs to be replaced.

661 Roof	Learning	Influence			Collaborative Environments			Systems Integration	Repeatable Performance		Cost Certainty			Time Reliability		
	Team Learning from Use	Integrated Processes	Job Growth / Creation	Economic Development	Indoor Air Quality	Functional Work Environment	Collaborative Work Environment	Energy Use Reduction through Integration	Scalable and Repeatable for Others	Non-proprietary Items	First Cost	Operating Cost (Utilities)	Operating Cost (Maintenance)	Minimize Construction Schedule Risk	Minimize Risk of Redesign	Notes
Weighting	3	2	2	2	2	2	1	3	2	2	3	3	3	2	2	
Structure																
High Bay: Replace existing plank (damaged only)	0	0	0	0	0	-	0	0	0	-	0	0	-	-	-	if cracks are visible, will need to be replaced
New SIP - high bay	0	0	0	0	0	0	0	+	0	0	+	+	0	+	+	
Perlin repair (water damaged)																
Perlin replacement (water damaged)																Requires planks above to be replaced
Perlin repair (fire damaged)																
Perlin replacement (fire damaged)																Requires planks above to be replaced
Insulation / Air Barrier																
High Bay: Insulation as part of R30 SIP																
High Bay: Insulation as part of R60 SIP																

RECOMMENDATION:

The team determined that the spalling and insulation uncertainties caused significant schedule risks. The cost savings for keeping the planks was not significant enough to offset these risks, so it was determined that SIPs would be used in the high bay area.

SIGNOFF (BSC members):

FOLLOW-UP:

BB, in conjunction with BBA, is to analyze the cost of R30 SIPs vs R60 and the price of the perimeter heating. After this pricing is assembled, the team will determine if there is cost benefit (initial and life cycle) in using R60 panels and deleting the perimeter heating.

Project Values Measurement

Affect on:	Green	Yellow	Red
Influence		x	
Repeatable Demonstration		x	
Learning		x	
Collaborative Environments		x	
Systems Integration	x		
Cost Certainty	x		
Time Reliability	x		

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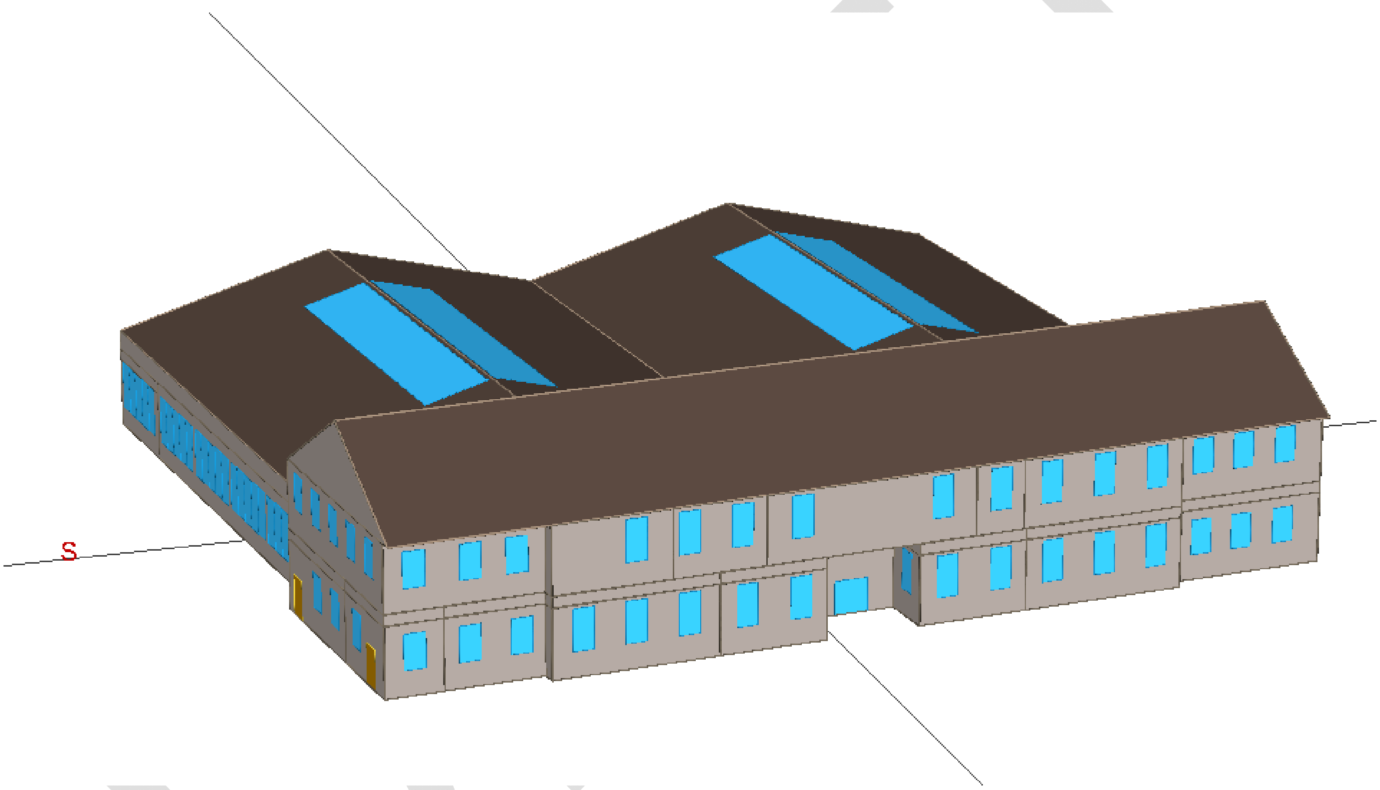
Appendix E: Schematic Design Energy Analysis Report, Atelier 10

Schematic Design Energy Analysis

Greater Philadelphia Innovation Cluster Building 661

April 6, 2012



atelier ten

Environmental Design Consultants + Lighting Designers

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Executive Summary

Atelier Ten has conducted a whole building energy analysis for Building 661 of the Greater Philadelphia Innovation Cluster (GPIC) renovation project at the Schematic Design (SD) stage. The purpose of this study is to:

- Benchmark the Proposed Design against a reference case, which is in accordance with the minimally compliant ASHRAE 90.1-2007 Appendix G building, in order to assess credits for LEED 2009 EAc1.
- Assess if design meets project goal of being 50% better than a typical comparable building (75th percentile of existing buildings using Energy Star rating system).
- Assess the effectiveness of various potential energy efficiency measures for HVAC, envelope and lighting.

Based on the current design assumptions, the results indicate that the Proposed Design performs 35% better in terms of annual energy consumption and 24% in terms of annual energy cost relative to the ASHRAE 90.1-2007 Baseline. With the addition of optional energy efficiency measures, 44% energy savings and 36% cost savings seem possible.

The Proposed Design and Potential Design would earn [#] or [#], respectively, of [#] possible LEED EA credit 1 points.

The preliminary Energy Star rating is [##], [meeting/ not meeting] the project goals.

Energy efficiency strategies currently incorporated into the Proposed Design include:

- Existing windows to be replaced with double glazed low-e argon-filled units with thermally broken frames
- Insulation (R-5) added to existing walls
- Insulation (R-30) added to existing roof
- Daylight dimming controls in perimeter spaces and high bay central space
- Occupancy sensors in most spaces
- Dedicated outdoor air unit
- Passive chilled beams
- Demand controlled ventilation for most spaces
- Efficient condensing boiler and air-cooled chiller
- Variable refrigerant volume system for first floor offices
- Displacement ventilation

Various options and alternates were evaluated in order to test their effect on building energy performance. Based on this analysis, Atelier Ten recommends:

- Add R-20 insulation to currently un-insulated walls, pending results of upcoming wall moisture and freeze/thaw studies
- Increase roof insulation to R-40
- Consider triple glazing
- Reduce lighting power densities at least 20% below ASHRAE 90.1-2007 maximum allowed
- Discuss the feasibility of naturally ventilating high bay area
- Add exhaust air energy recovery (enthalpy wheels) to air handling units

Further investigation and discussion with the design team and client is required to determine the feasibility of incorporating these measures.

Detailed assumptions for the analysis, including occupancy and internal loads, envelope construction, typical use schedules, and HVAC parameters, are presented at the end of this report and should be reviewed and confirmed by the design team and client.

Introduction

Atelier Ten conducted a Criteria Design (similar to Schematic Design) energy analysis for Building 661 of the Greater Philadelphia Innovation Cluster (GPIC), which is a 2-story building located at the Navy Yard in Philadelphia, Pennsylvania. The building will be undergoing a complete renovation, with a program consisting of approximately 38,000 ft^2 of conditioned area including offices, research spaces, conference rooms, and symposia.

The energy model is based on the March 7, 2012 drawing set and conversations with the design team. The model includes building geometry, construction types, material properties, internal loads, and HVAC systems. Modeling assumptions for operating schedules, set points, lighting power densities, equipment power densities, and HVAC systems and efficiencies were based upon information gathered from the design team.

Atelier Ten created energy models using eQUEST v3.64 (DOE-2.2 simulation engine). These energy models allow for the comparison of relative energy use throughout the year and assist in identifying specific energy demands for heating, cooling, pumps, fans, lighting, equipment, and hot water. The first energy model, referred to as “Baseline Design”, meets the minimum requirements stipulated in Appendix G of ASHRAE 90.1-2007. The second energy model, referred to as “Proposed Design”, represents the current design. Atelier Ten created additional models to evaluate various energy efficiency measures (EEMs) and alternates considered for this project. At the Criteria Design phase, the EEMs are selected to understand the model’s sensitivity or to test items that have space and first cost implications. The scenarios for these models are described below:

- Baseline Design (ASHRAE 90.1-2007 compliant Baseline model)
- Proposed Design (Current design based on SD documents and conversations with design team)
- Additional Wall Insulation from R-10 through R-40
- Additional Roof Insulation from R-40 to R-50
- Replace proposed double glazing with triple glazing
- Reduce lighting power densities by 10%, 20%, and 30% below ASHRAE 90.1-2007 allowed
- Assume high bay space is entirely daylit
- Add exhaust air energy recovery to air handling units
- Use evaporatively cooled condensers for chiller and rooftop unit
- Naturally ventilate high bay space
- Insulate exterior of wall so mass is exposed to interior
- Add thermal mass to spaces
- Potential Design: Includes R-20 walls, R-40 roof, triple glazing, 20% LPD reduction, exhaust air energy recovery, and natural ventilation for high bay space

Ground source heat pumps have not yet been modeled but will be modeled later in the Criteria Design phase.

This report begins with a summary of results and then provides discussion about the major energy drivers in the building. Next, the report discusses the results of the analysis with respect to annual energy and utility cost savings for all the measures listed above. This report concludes with recommendations, list of next steps for the design team, and an appendix with the energy model assumptions.

At this point, the design team should be made aware that the results from this analysis are preliminary and are based on many assumptions. The results will change as the design progresses and based on the information provided in the future. Details regarding assumptions used can be found in the appendix of this report.

Energy models are representations of the designed building and its future operations. Energy modeling is a design optimization tool which predicts the energy performance of a building. The results from the energy model are accurate in terms of comparative evaluations of energy optimization measures assuming that all the other assumptions remain consistent. However, because energy model results rely on many assumptions about building occupancy patterns, they should not be construed as an absolute prediction of future building energy use.

Summary of Results

The energy model estimates various energy uses throughout the year and identifies specific uses for heating, cooling, pumps, fans, lighting, equipment and hot water. Figure 1 summarizes these end uses in terms of annual site energy (million Btus). Based on the modeling assumptions, the Proposed Design shows an annual energy consumption savings of around 35% over an ASHRAE 90.1-2007 Appendix G compliant building.

Heating energy in the Proposed Case is significantly lower compared to the Baseline Building, primarily due to reduced heating loads from the additional wall insulation and improved glazing performance, along with chilled beam hydronic heating, efficient boiler, and demand controlled ventilation. There is a significant reduction in space cooling energy due to improved glazing and chilled beam systems, while fan energy is reduced due to the need to only supply primary ventilation air to the chilled beams and low pressure drop for the variable refrigerant flow fan coil units. Finally, daylight dimming contributes to lighting savings, as well as cooling savings due to reduced internal gains.

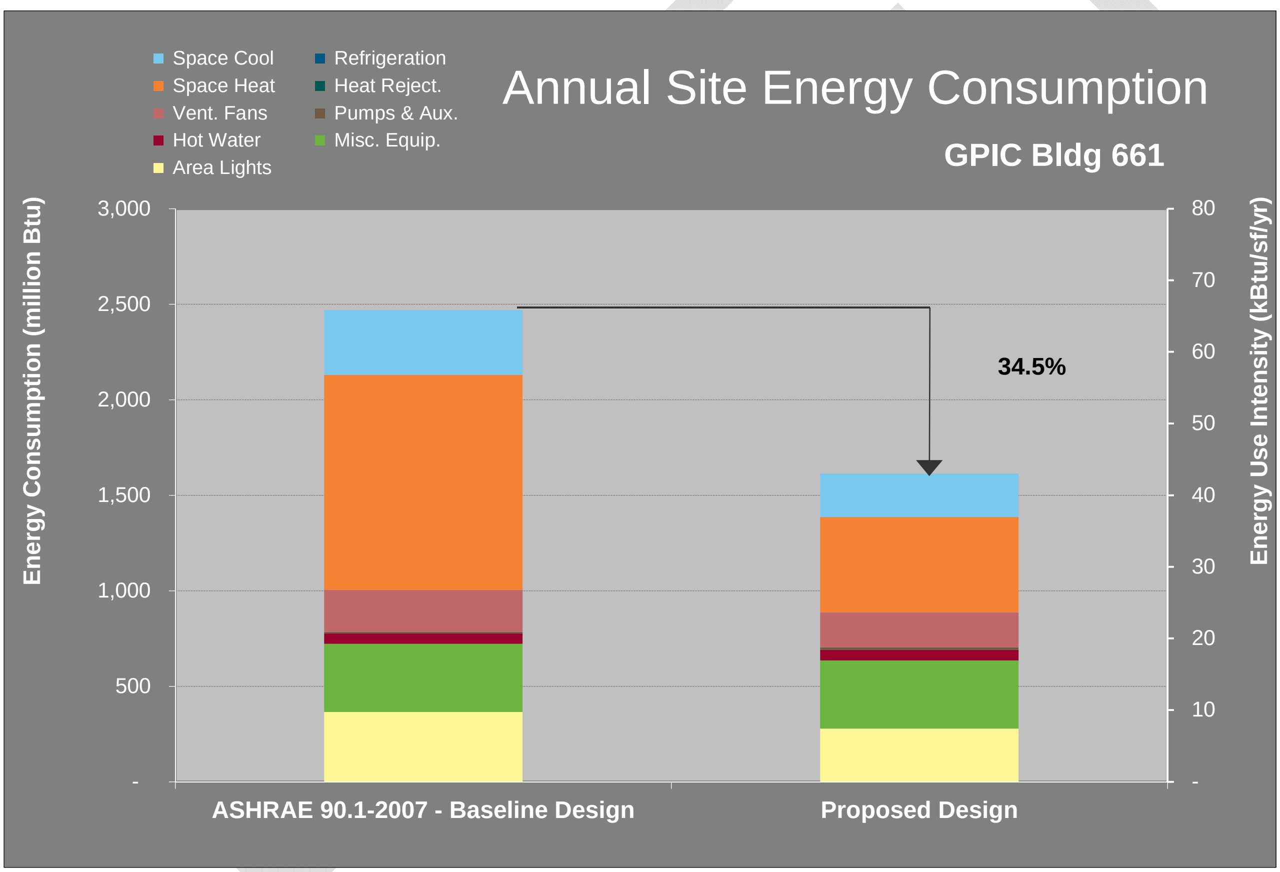


Figure 1: Annual Energy Consumption Comparison

The Proposed Design shows an annual energy cost savings of around 24% compared to an ASHRAE 90.1-2007 Appendix G compliant building. Large natural gas savings are achieved through the heating energy reduction, and electricity savings result primarily from cooling and lighting savings. Note that the cost savings percentage (24%) is lower than the energy savings percentage (35%) since most of the energy savings are coming from lower natural gas use, which has a lower cost per unit energy cost than electricity.

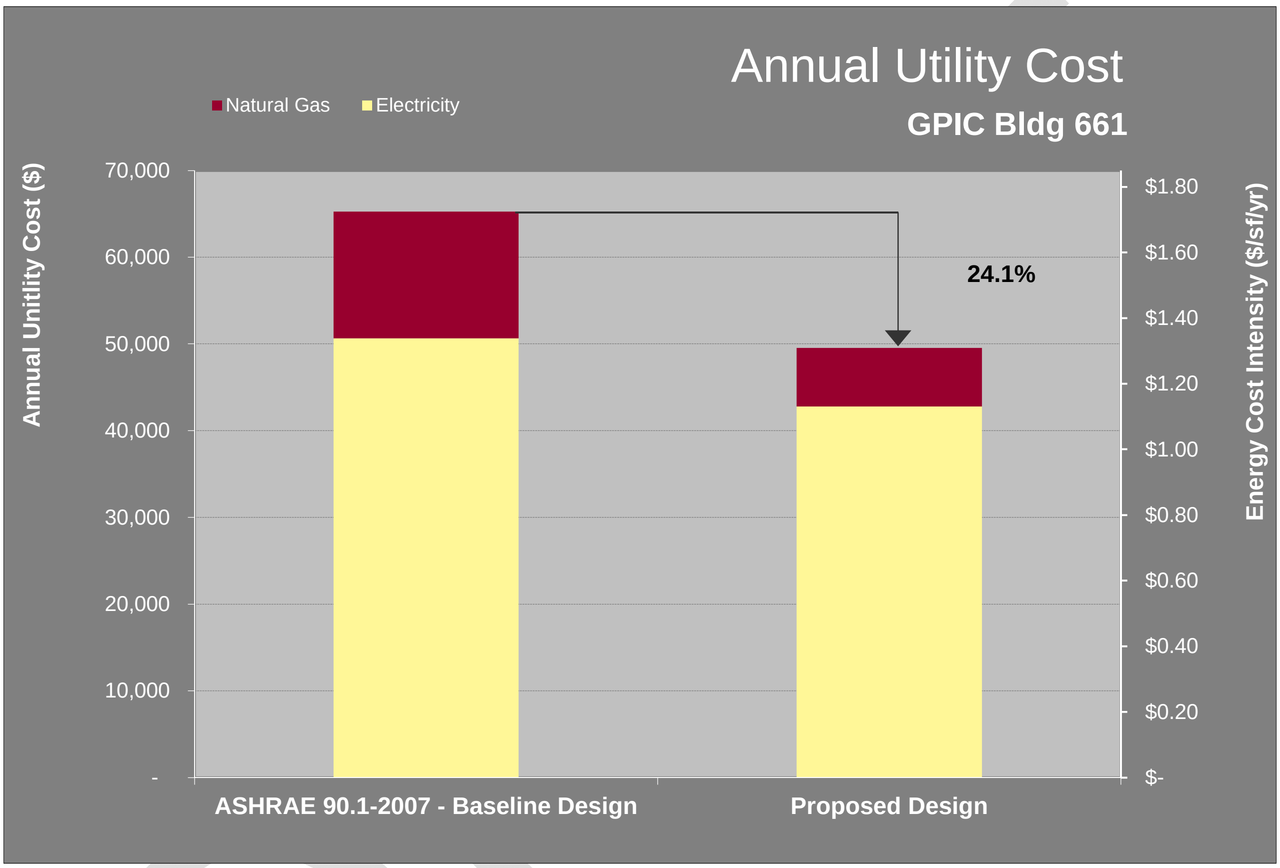


Figure 2: Annual Energy Cost Comparison

Since space heating remains the dominant energy end use for the building, different levels of wall insulation were tested. In the graph below, the heating energy use decreases significantly between by increasing from R-5 to R-20 insulation. There is a less significant decline in heating energy between R-20 and R-40. Wall insulation levels of approximately R-20 to R-30 are recommended, pending constructability issues and future freeze/thaw analysis.

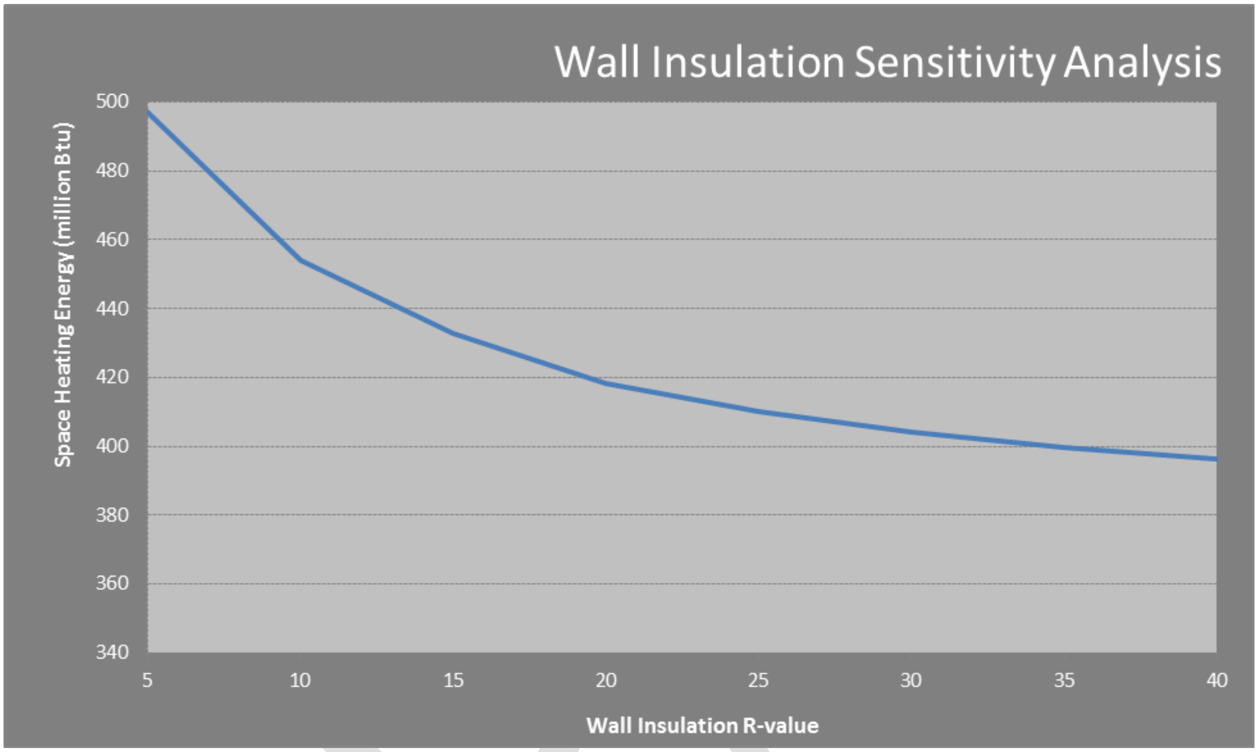


Figure 3: Relationship between wall insulation and space heating.
Proposed Design Case is modeled as R-5. Potential Case is modeled as R-20.

The energy model confirms the design team's intuition that the building's energy use is very sensitive to the building envelope's infiltration rate. In this energy model, the Proposed Design Case and Baseline Case are currently both assume infiltration rate of 0.4 ACH (a very air tight building). In order to take credit for an infiltration rate reduction in the Proposed Design Case, the infiltration rate would need to be measured before and after the renovation. This test may be part of this project's scope, and would match its research intent, but has yet to be confirmed by GPIC. It should also be noted that the modeling guidelines in ASHRAE do not provide strict guidelines for improvements in infiltration.

For reference, in BBA's load calculations, the typical building's infiltration rate is 0.8 ACH and the speculative extremely air tight building's infiltration rate is 0.4 ACH. The graph below shows this infiltration rate reduction would decrease the building's energy consumption by about 20%, indicating that air tightness is a very important design consideration in this project. The project team should consider blower door tests before and after the renovation to quantify improved air tightness and take credit for it in the energy model.

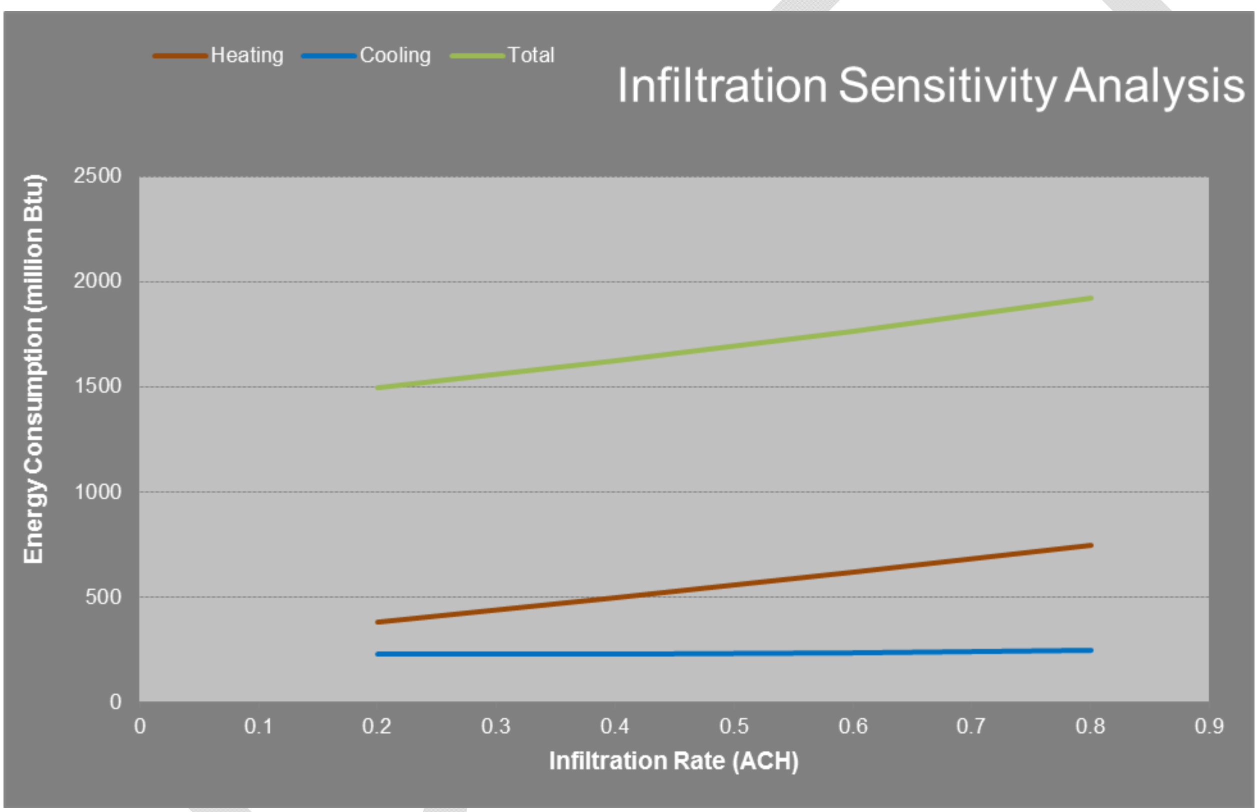


Figure 4: Relationship between infiltration rate and space heating/cooling.

Energy efficiency measures

Atelier Ten evaluated several potential energy efficiency measures and alternates for the project. Results are shown in Figures 5 through 8; the first two graphs are for envelope measures while the second two graphs are for lighting and HVAC measures.

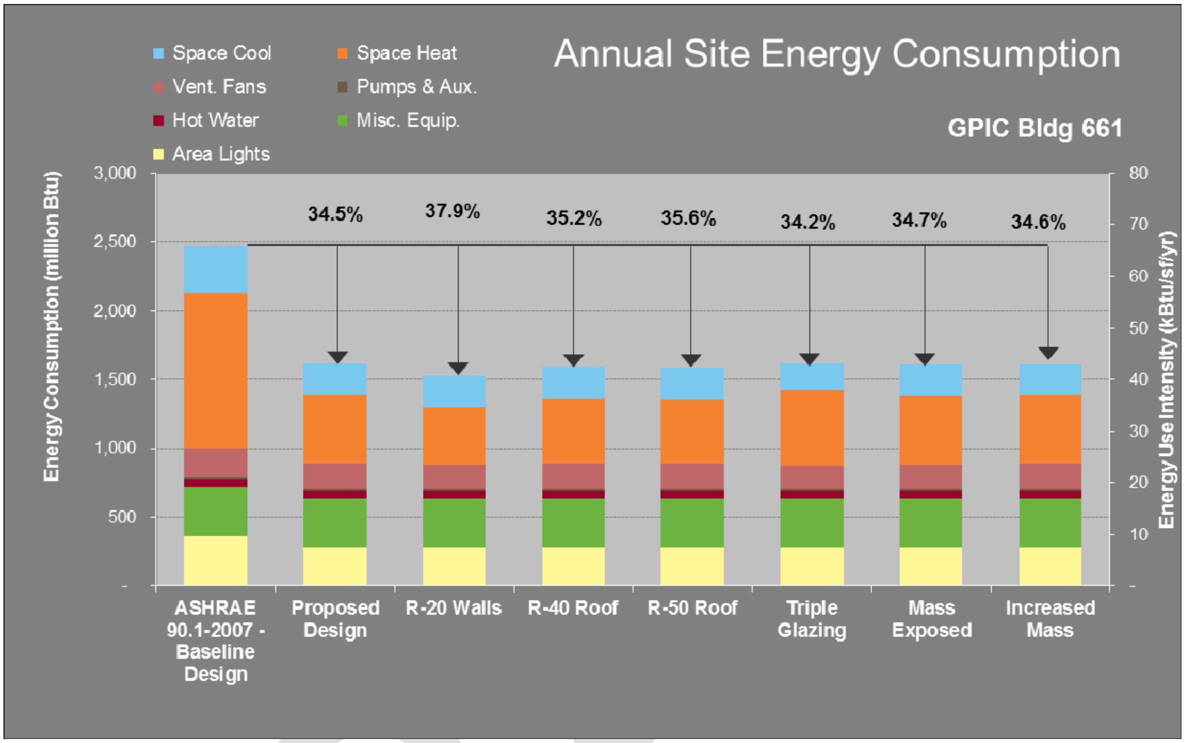


Figure 5: Annual Energy Consumption Comparison (envelope energy efficiency measures).

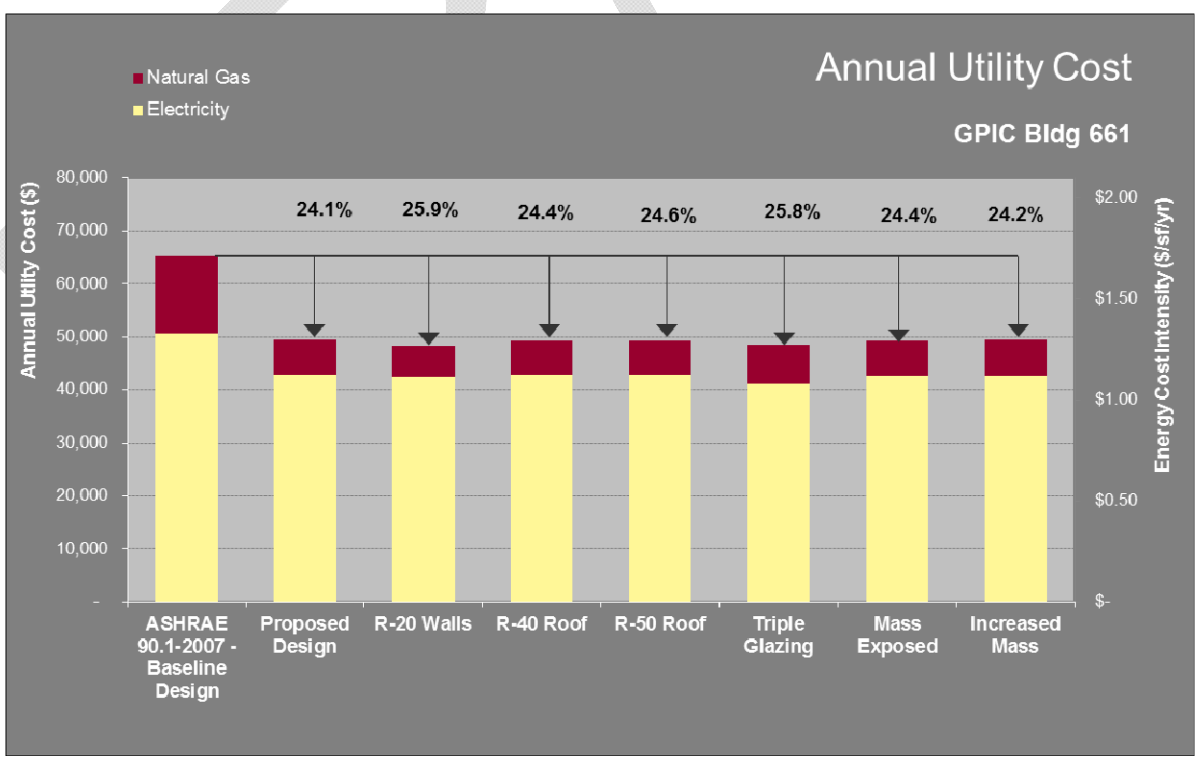


Figure 6: Annual Energy Cost Comparison (envelope energy efficiency measures)

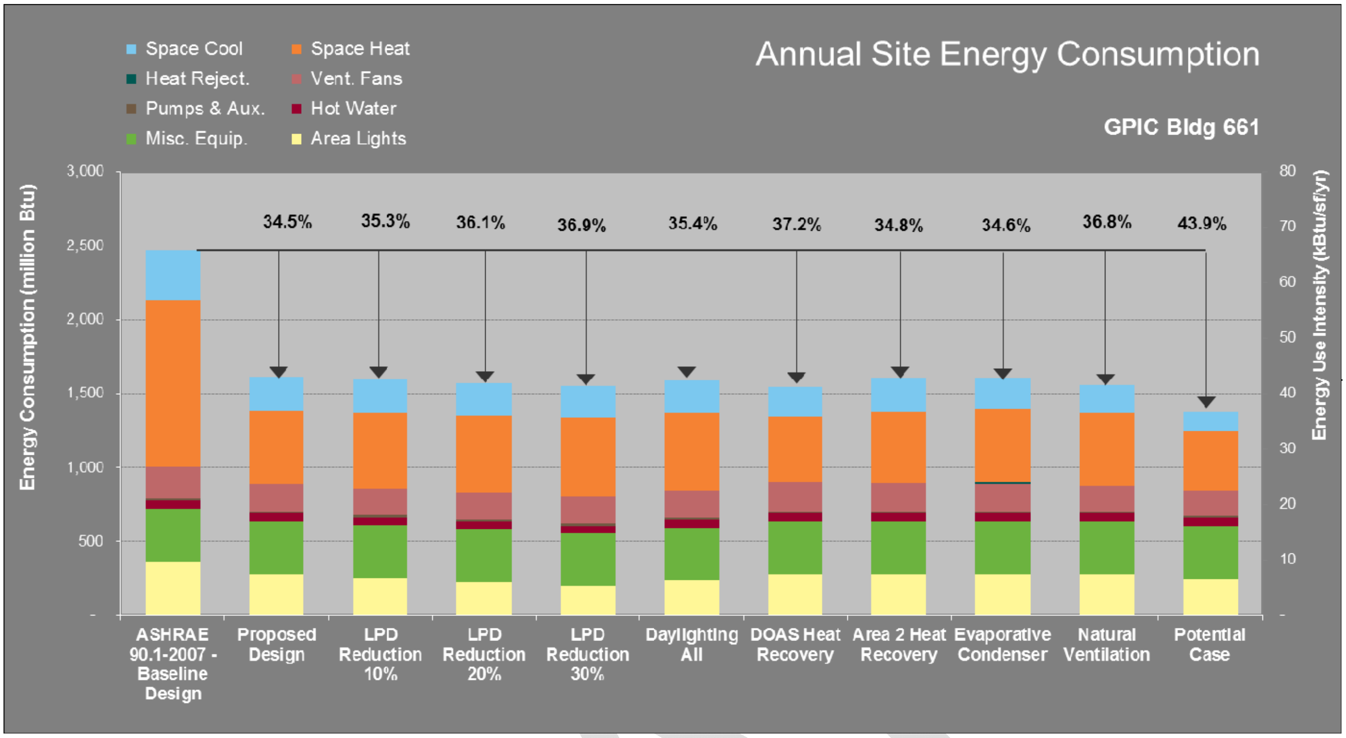


Figure 7: Annual Energy Consumption Comparison (Lighting/HVAC energy efficiency measures)

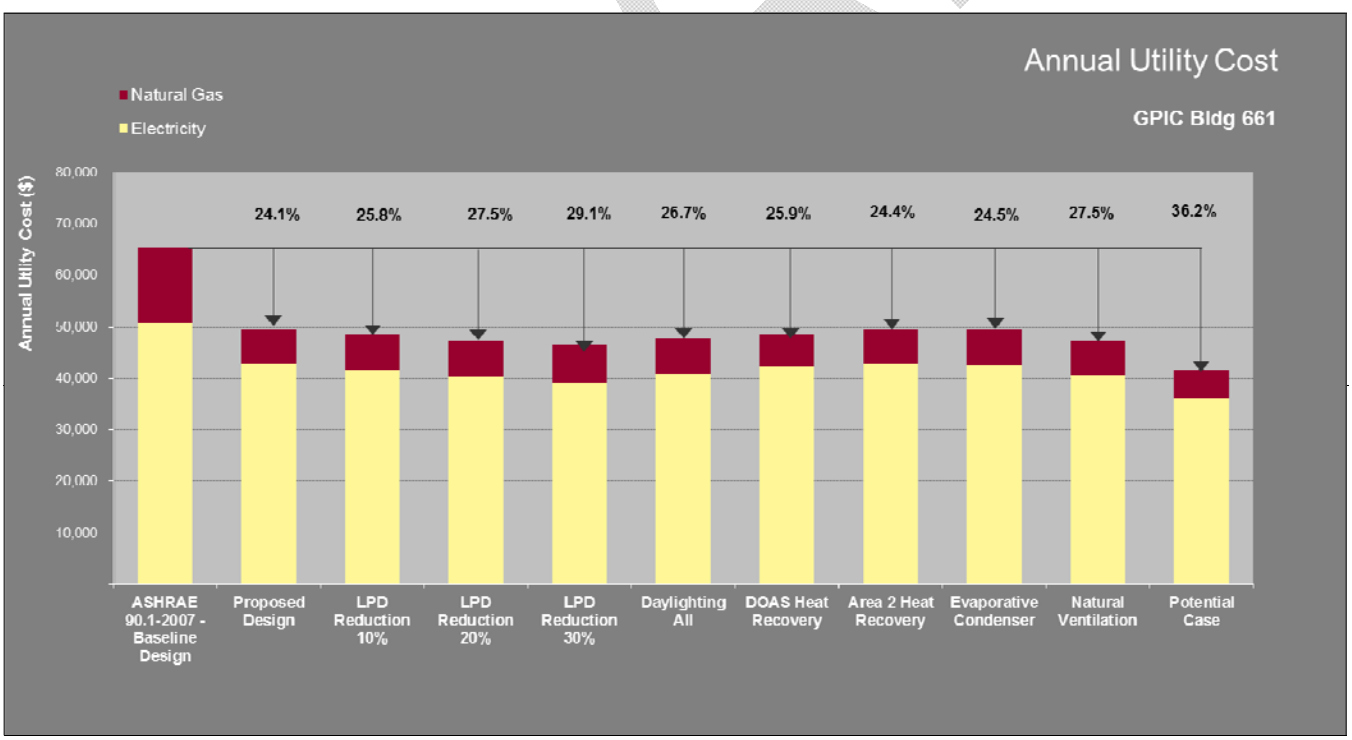


Figure 8: Annual Energy Cost Comparison (Lighting/HVAC energy efficiency measures)

Wall Insulation: Based on the results shown in Figure 3 and 5, increasing wall insulation from R-5 to R-20 shows a 3.4% energy savings, and 1.9% cost savings, which is significant. Heating energy is greatly reduced, and cooling and fan energy are somewhat reduced. Wall insulation value of R-20 to 30 is recommended taking into consideration that the energy savings beyond R-20 may or may not outweigh added first cost or constructability issues. Note this is modelled as continuous insulation. If insulation is placed between studs, a lower R-value would be achieved and savings would be reduced.

Roof Insulation: Increasing the Proposed Design's roof from R-30 to R-40 or R-50 results in 0.7% or 1.1% reduction in energy use, mainly by reducing heating energy. These modest savings will likely not justify the additional first cost and constructability issues.

Triple Glazing: Replacing all double glazed units (including skylights) with triple glazed units increase heating and decreases cooling and fan energy, probably because of the improved SHGC. This results in a minor 0.3% decrease in energy use but notable 1.7% savings in energy cost. Other considerations should influence the glazing selection, including thermal comfort (downdrafts during winter), external shading, and glare. For example, an improved SHGC could also be achieved with an external shading device designed to block summer solar heat gain while admitting winter solar heat gain. The design team should consider that direct passive solar gain may bring glare problems. See Appendix for more info on glazing performance.

Mass Exposed: This EEM moves the wall insulation from interior to exterior to gauge the value of the thermal mass of the existing masonry wall to the intrerior. Cooling and fan energy are slightly reduced for a 0.2% energy use and 0.3% energy cost savings. Based on this analysis, this measure is not recommended, especially due to the potential historic preservation issues with insulating the exterior.

Increased Thermal Mass: This measure shows only 0.1% energy use and cost savings as currently modeld in eQUEST. The limitations in the software allow only an approximation of increased thermal mass by adding dense furniture into the space. Specifically, the model increased the furniture weight from 0.2 lbs/ft^2 to 0.4. If this measure is of further interest to the team, energy savings could be tested in different softwares such as the phase change material manufacturer's Energy Plus model, one of GPIC's models, or a separate Atelier Ten model.

LPD Reduction: Reducing lighting power density by 20% below ASHRAE 90.1-2007 maximum levels results in a significant energy reduction, both in lighting and cooling, due to lower internal gains. This is recommended and is the current intent of the A10 lighting designers. A 30% LPD reduction is still on the table as a stretch goal.

Daylight high bay space: This EEM replaces the Proposed Design daylighting with a more aggressive daylighting case to test its potential reduction in electric lighting and cooling. In this EEM, high bay work areas are fully daylit (electric lights are scheduled to be only 10% on during daylight hours). The 0.9% energy use and 2.6% energy cost savings are significant and affirm the team's intuition that daylight is a design driver. The team should continue efforts to design the envelope, shading, interior program layout, and electric lighting to maximize useful daylight levels and electric light dimming.

Heat Recovery: The Baseline and Proposed Design Cases do not have heat recovery, and this EEM adds enthalpy wheel heat recovery in the dedicated outside air system (DOAS) serving Area 1 and Packaged Rooftop Unit serving Area 2. This reduces heating and cooling energy while increasing fan energy. The heat recovery on the DOAS is quite effective, with 2.7% energy use and 1.8% energy cost savings, and is recommended. The heat recovery on the rooftop unit is shows only 0.3% energy use and cost savings, and is recommended as second priority, if the added first cost and space required are not prohibitive. See Appendix for heat recovery performance.

Evaporatively Cooled Condenser: Adding evaporatively cooled condensers to the air-cooled chiller serving Area 1 and packaged rooftop unit serving Area 2 results in a 0.1% energy use and 0.4% energy cost savings. Based on experience, these savings are lower than expected, perhaps because the default DOE2 software chiller is not a good fit for this project. This measure should be tested again in the next phase when specific actual chiller performance is known and modelled.

Naturally Ventilate High Bay Space: For operating hours when outdoor air is between 55˚ F and 75˚ F drybulb temperature and less than 0.012 lbda/lb humidity ratio, windows assumed to be open and providing cooling to high bay spaces. The reduced cooling and fan energy result in overall 2.3% annual energy use and 1.8% energy cost savings. This is recommended for further discussion regarding feasibility of operable air inlet and outlet locations and control, acceptable temperature ranges, and night flushing.

Potential Case: This case includes R-20 walls, R-40 roof, triple glazing, 20% LPD reduction, exhaust air energy recovery, and natural ventilation for high bay space. This shows 44% energy savings and 36% cost savings are an ambitious yet achievable goal for this project.

Energy Star Target Finder

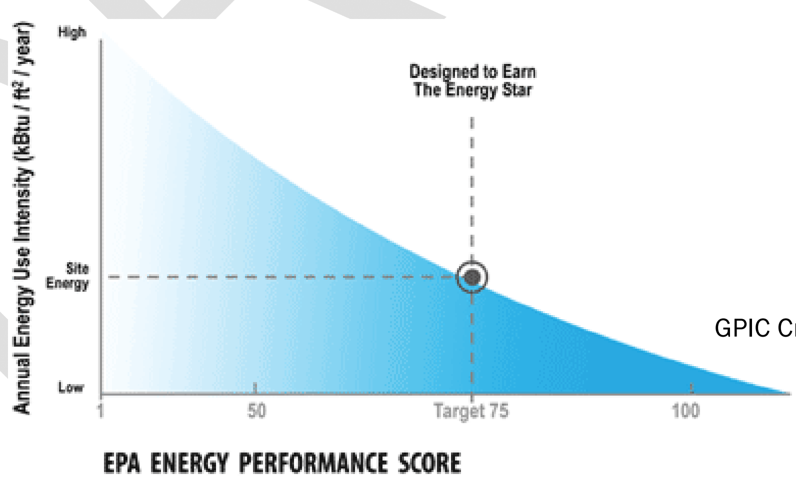
Another goal of the SD energy analysis is to assess if design is 50% better than a typical comparable building (75th percentile of existing buildings using Energy Star rating system). This goal was established in the sustainability workshop with the design team and GPIC during the Conceptualization Phase in January 2012.

Preliminary Energy Star building 661 Proposed Design rating is likely between 90 and 95, which exceeds the target rating of 75. The current projected rating is excellent, but should be viewed with the understanding it is built upon the current project data and could change based on future project data. The inputs for the Energy Star Target Finder include zip code, program, area, operating hours, workers, number of personal computers, air conditioning, heating, and estimated design energy.

For reference, a median existing building of this type has a rating of 50. The EPA provides reference targets that are based on the energy consumption of existing buildings, as collected by the U.S. Department of Energy, Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS).

Upon completion, if the project meets or exceeds the target rating of 75, the can apply for “Designed to Earn the ENERGY STAR Certification” and then verify actual performance to earn the “Energy Star Label.”

For more info on inputs and outputs for the Energy Star Target Finder, please see the Appendix.



GPIC Criteria Design Model

Energy Start Target Finder Graph

Recommendations and Next Steps

Atelier Ten recommends R-20 to R-30 walls, R-40 roof, 20% to 30% LPD reduction, exhaust air energy recovery, and natural ventilation for the high bay space be considered for inclusion in the design. Further investigation and discussion with the design team and client is required to determine the feasibility of incorporating these measures. Note that results may change as the design progresses and based on the information provided in the future.

The next steps during the current Criteria Design phase (similar to a traditional Schematic Design phase) for the GPIC building 661 are:

- Design team to review the assumptions used in the energy model (attached in the Appendix)
- Design team to consider including the recommended measures in the project
- Atelier Ten to model ground source heat pumps as an energy efficiency measure for building 661

Balfour Beatty to provide costs for measures requiring further evaluation such as life cycle cost analysis. Those measures will be identified in conversation with the team.

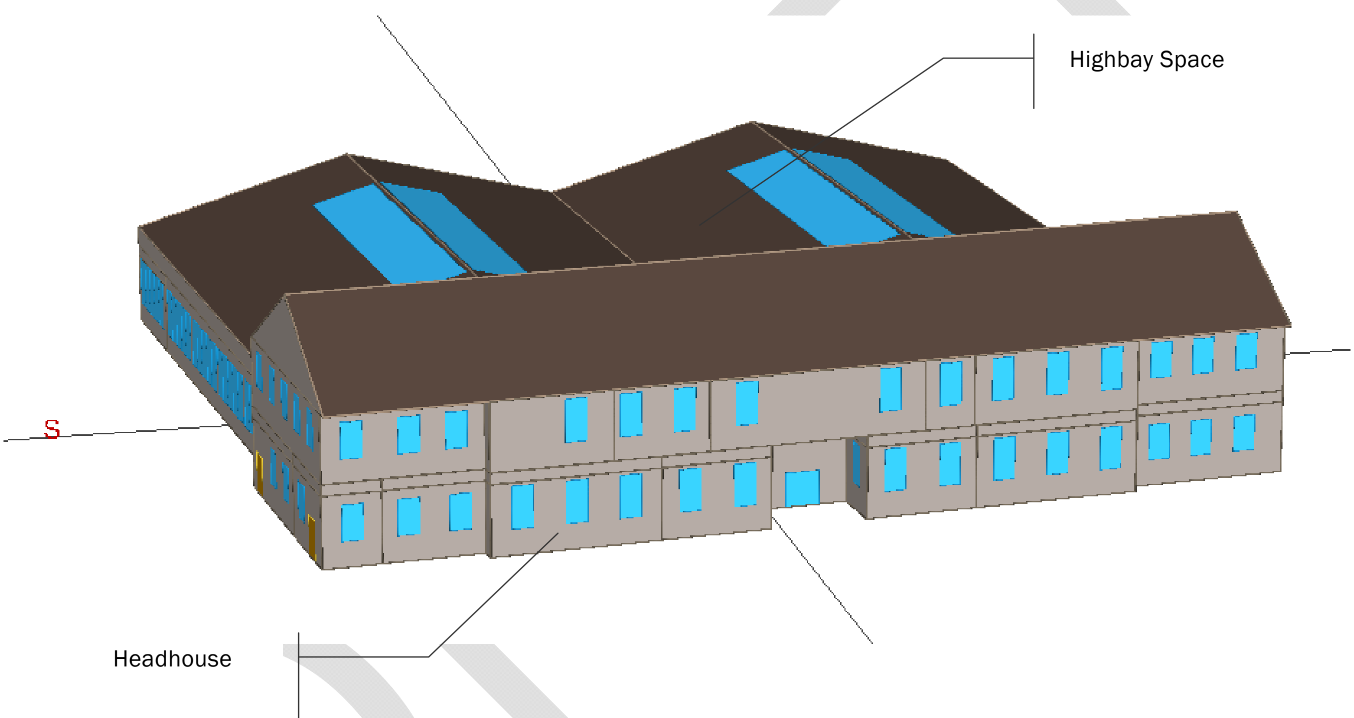
During the upcoming Design & Implementation phase (similar to a traditional Design Development phase), open issues that may require more detailed analysis include:

- benchmark CO_2 savings
- compare triple glazing versus double glazing (possibly with external shading) in terms of first cost, annual energy cost, replicability, thermal comfort, and glare.
- desiccant dehumidification & solar thermal recharge (from UTC analysis)
- phase change materials or thermal mass
- expanded comfort zone with natural ventilatiuon
- night flushing
- direct/indirect evaporative cooling at DOAS and/or rooftop unit
- removal of perimeter radiation
- evaporatively cooled condenser for chiller and rooftop unit using actual chiller equipment performance in model

Appendix

Appendix A: General modeling parameters

Analysis Tool: eQUEST (DOE 2.2 Engine) v3.64
Weather File: DOE 2.2 TMY2 weather file for Philadelphia, PA
ASHRAE Climate Zone: 4A
Building Area (as simulated with DOE 2.2): appx. 38,000 gross ft²
Number of Floors: 2 above grade, mezzanine
Existing Renovation / New Construction: 100% / 0%
Principal Heating Source: Hot Water from Condensing Boilers
Principal Cooling Source: Chilled Water from Air-cooled Chiller



Three dimensional representation of energy model

Appendix B: Building envelope construction

Building Element	Proposed Design	Baseline Design
Envelope		
Exterior Wall Construction	Typical Wall Construction: 8" Brick 1" Airspace 4" CMU 1" continuous rigid insulation (R-5) Assembly U-Factor: 0.112 Btu/hr-ft²-°F (R-9)	Existing Wall Construction: 8" Brick 1" Airspace 4" CMU Assembly U-Factor: 0.255 Btu/hr-ft²-°F (R-4)
Roof Construction	Typical Roof: R-30 continuous insulation Assembly U-Factor: 0.032 Btu/hr-ft²-°F (R-31)	Existing Roof: Headhouse: R-19 batt insulation (many holes) Assembly U-Factor 0.10 Btu/hr-ft²-°F (R-10) Highbay: R-20 insulation above deck Assembly U-Factor 0.048 Btu/hr-ft²-°F (R-21)
Slab-on-Grade Construction	Concrete Slab-on-Grade Assembly F-Factor: 0.73 Btu/hr-ft-°F	ASHRAE 90.1-2007 Appendix G Slab-on-Grade Table 5.5-5 Unheated Slab Assembly F-Factor: 0.73 Btu/hr-ft-°F
Window-to-Wall Ratio	21%	13%
Glazing Description	Typical Glazing: Double glazed units (VE 1-2M with argon) with thermally broken aluminum frame	Existing Glazing: Double glazed units with aluminum frame
Glazing U-Factor	Center-of-Glass: 0.25 Btu/hr-ft²-°F Assembly: 0.35 Btu/hr-ft²-°F	Existing Glazing: Assembly: 0.67 Btu/hr-ft²-°F
Glazing SHGC	0.37	Existing Glazing: 0.71
Glazing VLT	70%	Existing Glazing: 80%
Infiltration	0.4 ACH	0.4 ACH

Appendix C: Building occupancy, lighting power density and equipment load

Building Element	Proposed Design	Baseline Design
Lighting		
Interior Lighting Power Density	Same as Baseline Design	ASHRAE 90.1-2007 Compliant (Table 9.6.1) Offices/Labs: 1.1 W/sf Conference Rooms: 1.3 W/sf Symposium, iCon Lab: 1.4 W/sf Mechanical: 1.5 W/sf Storage: 0.8 W/sf Corridors: 0.5 W/sf
Daylighting Controls	Continuous daylight dimming controls in perimeter spaces and highbay central area (50 footcandle illuminance target)	None.
Occupancy Sensors	Present in most areas, including offices, lab rooms, conference rooms, storage areas, mechanical rooms (10% LPD credit for spaces with occ sensors)	In areas required by Section 9.4.1.2 (classrooms, break rooms, conference rooms).
Exterior Lighting Power Density	Same as Baseline Design	ASHRAE 90.1-2007 Compliant
Equipment		
Receptacle Equipment	Lab rooms / Offices: 1.0 W/sf Conference Rooms: 2.0 W/sf Server: 10 W/sf	Same as Proposed Design
Occupancy		
Occupant Density	Lab rooms: 100 sf/person Offices: 120 sf/person Conference areas: 30 sf/person i-Con lab: 60 people Symposium: 114 people	Same as Proposed Design
Building Schedule	Normal hours: 7 a.m. – 7 p.m. Monday through Friday	Same as Proposed Design

Appendix D: Building occupancy, lighting and equipment schedules

Typical schedules as percentage of design value is shown below.

Typical Use Schedule

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
12:00 AM	1:00 AM	0%	0%	5%	2%	20%	6%
1:00 AM	2:00 AM	0%	0%	5%	2%	20%	6%
2:00 AM	3:00 AM	0%	0%	5%	2%	20%	6%
3:00 AM	4:00 AM	0%	0%	5%	2%	20%	6%
4:00 AM	5:00 AM	1%	0%	8%	2%	21%	6%
5:00 AM	6:00 AM	2%	0%	29%	2%	34%	6%
6:00 AM	7:00 AM	67%	0%	73%	2%	74%	6%
7:00 AM	8:00 AM	85%	0%	87%	2%	87%	6%
8:00 AM	9:00 AM	90%	0%	90%	2%	90%	6%
9:00 AM	10:00 AM	88%	0%	90%	2%	90%	6%
10:00 AM	11:00 AM	75%	0%	90%	2%	90%	6%
11:00 AM	12:00 PM	54%	0%	90%	2%	90%	6%
12:00 PM	1:00 PM	54%	0%	90%	2%	90%	6%
1:00 PM	2:00 PM	75%	0%	90%	2%	90%	6%
2:00 PM	3:00 PM	88%	0%	90%	2%	90%	6%
3:00 PM	4:00 PM	90%	0%	90%	2%	90%	6%
4:00 PM	5:00 PM	89%	0%	89%	2%	90%	6%
5:00 PM	6:00 PM	82%	0%	86%	2%	90%	6%
6:00 PM	7:00 PM	66%	0%	76%	2%	84%	6%
7:00 PM	8:00 PM	29%	0%	48%	2%	49%	6%
8:00 PM	9:00 PM	12%	0%	30%	2%	31%	6%
9:00 PM	10:00 PM	10%	0%	16%	2%	23%	6%
10:00 PM	11:00 PM	10%	0%	10%	2%	20%	6%
11:00 PM	12:00 AM	10%	0%	6%	2%	20%	6%

Note that spaces such as the i-Con Lab and Symposium are assumed to be fully occupied two times per week.

Appendix E: HVAC system parameters

The building is served by three different system types. Spaces in the high bay area (Area 1) are served by 4-pipe passive chilled beams and a dedicated outdoor air (DOA) unit (mezzanine spaces have underfloor air distribution). Chilled water is provided by an air-cooled chiller and hot water by a condensing boiler. Most spaces in the headhouse (Area 2) are served by a packaged rooftop unit with DX cooling and gas furnace heating, with underfloor air distribution on the second floor. Offices on the first floor of the headhouse (Area 3) are served by variable refrigerant flow fan coil units with natural ventilation.

Design Conditions

The chart below show interior space design conditions:

Space	Heating temp °F	Cooling temp °F	High RH %	Low RH %
General Areas	Occupied: 70 Unoccupied: 55	Occupied: 76 Unoccupied: 80	55%	0%

Description of the Proposed Building and Baseline Building System Parameters

The chart below describes the HVAC modeling assumptions for the Proposed and Baseline Building models.

Building Element	Proposed Design	Baseline Design
Mechanical Systems		
Primary HVAC System Type	Area 1 (high bay spaces): Dedicated outdoor air unit supplies outdoor ventilation air to meet latent loads with passive chilled beams providing sensible heating and cooling	ASHRAE 90.1-2007 Appendix G System Type 5: Packaged VAV with reheat One System per Floor
Other HVAC System Type	Area 2 (headhouse): Packaged VAV rooftop unit with DX cooling and gas furnace heating Area 3 (headhouse offices): Variable refrigerant volume units	System Type 3: Packaged Rooftop Air conditioner Serving server room
Air Distribution	Overhead Mixed for most spaces Underfloor air distribution for 2nd floor mezzanine and headhouse spaces	Overhead Mixed
Air-Side Cooling		
Minimum Supply Temperature	Overhead mixed: 55°F UFAD: 63°F	55°F
Cooling Source	Chilled water for chilled beams and DOAS DX cooling for packaged VAV rooftop unit	Same as Proposed
Supply Air Temperature Control	Reset higher by 5°F under minimum cooling load conditions	Reset higher by 5°F under minimum cooling load conditions
DX Efficiency	Area 2 Packaged RTU: 9.3 EER Area 3 VRF system: 3.7 COP	9.3 EER
Air-Side Heating		
Maximum Supply Temperature	90°F	90°F
Heat Source	Hot Water for chilled beams and DOAS Gas furnace for packaged VAV rooftop unit	Hot Water
Zone Heating	Chilled beams, VRF fan coils	VAV terminal reheat

Heating Efficiency	Gas furnace: 80% VRF system: 4.1 COP	80%
Outdoor Air		
Design Ventilation Rates	ASHRAE 62.1-2007 minimum rates: DOAS: 2,500 cfm Area 2 sytem: 2,600 cfm Area 3 system: Naturally ventilated	Same as Proposed Design
Air-side Economizer Cycle	Area 2 system has drybulb economizer, high limit 65°F	None (not required).
Heat Recovery	None.	None (not required).
Demand Control Ventilation	Carbon dioxide sensors in most spaces modulates outdoor air based on occupancy	Symposium space
Fan Power and Flow		
Fan Power	AHUs: 5.0" w.g. supply, 2.5" w.g. return VRF Fan coil units: 1.0" w.g.	ASHRAE 90.1-2007 Appendix G fan power
Minimum Flow Ratio	Area 1 System: Primary airflow to meet ventilation requirements Area 2 System: 30%	0.4 cfm/sf
Water-Side Cooling		
Chiller Type	Air-cooled chiller	N/A
Chiller Efficiency	1.0 kW/ton	N/A
Chilled Water (CHW) Loop	Low temp loop: 44°F supply / 56°F return Chilled beam loop: 55°F supply / 61°F return	N/A
CHW Loop Temp Reset Parameters	Reset up to 54°F based on load	Same as Proposed Design
CHW Loop Configuration	Variable primary flow	Constant primary / variable secondary
Primary CHW Pump Speed Control	Variable speed drive	Variable speed drive
Water-Side Heating		
Boiler Type	Condensing Boiler	Natural Draft Boiler
Boiler Efficiency	90%	80%
Hot Water Loop	180°F supply / 140°F return	180°F supply / 130°F return
HW Loop Temp Reset Parameters	Reset down based on OA temperature	Reset down based on OA temperature
HW Loop Configuration	Variable primary	Variable primary
Domestic Water Heating		
DHW Equipment Type	Natural gas	Same as Proposed Design
DHW Flow	0.4 GPM	Same as Proposed Design
DHW Efficiency	80%	80%
Temperature Controls	120°F distribution temperature	Same as Proposed Design

Appendix F: Utility Rates

Utility rates used in the energy model are listed below.

Electricity (PECO):
- $0.1108 / kWh
- $4.96/kW
- $16.41/month

Natural Gas (Philadelphia Gas Works:
- $1.22 / therm
- $18.00/month

Appendix G: Energy efficiency measure assumptions

Energy Efficiency Measure	Description
Wall Insulation Sensitivity Analysis	Add varying levels of continuous insulation to inside of existing walls (R-10 through R-40, note that R-5 is assumed for Proposed Design)
Roof Insulation Sensitivity Analysis	Add varying levels of continuous insulation to roof (R-40 through R-50, note that R-30 is assumed for Proposed Design)
Triple Glazing	Replace all double glazed units with triple glazed units (center-of-glass U-value-0.21, SHGC-0.20, VT-0.63). Includes skylights.
Lighting Power Density Reduction	Reduce LPDs by 10%, 20%, and 30% below ASHRAE 90.1-2007 maximums
Daylight Entire High-Bay space	Assume work areas are fully daylit (schedule electric lights to be on 10% during daylight hours)
Exhaust Air Energy Recovery	Enthalpy wheel heat recovery in DOAS and Packaged Rooftop Unit serving area 2 (75% total effectiveness, 1" w.g. static pressure)
Evaporatively Cooled Condensers	Air-cooled chiller and packaged rooftop unit serving Area 2 have evaporatively cooled condensers
Naturally Ventilate High Bay Space	For hours when outdoor air is between 55F and 75F drybulb temperature and less than 0.012 lb/lb humidity ratio, windows assumed to be open and providing cooling to high bay spaces
Insulate Exterior of Wall	Insulation is placed on the exterior of the wall, exposing the mass to the interior
Increased Thermal Mass	Furniture weight in spaces increased from 2 lb/sf to 4 lb/sf
Potential Case	Includes R-20 walls, R-40 roof, triple glazing, 20% LPD reduction, exhaust air energy recovery, and naturally ventilated high bay space

Atelier Ten analyst: DTD
Report reviewed by: ST/WKM

Appendix H: Energy Star Target Finder Assumptions and Results

Input Page

Target Finder

* REQUIRED
Select a target rating and/or compare your Design Energy to the target.

1. Facility Information

*Zip Code	19143	Facility Name	GPIC 661		
Address		City		State	

2. Facility Characteristics

*Select Space Type(s) for this project.

[Space Types]

Office — Delete

*Gross Floor Area	*Weekly operating hours	*Workers on Main Shift	*Number of PCs	*Office Air-Conditioned	*Office Heated
38000 Sq. Ft.	55 Hours	316	107	50% or more	50% or more

3. The Target[1]

Target Rating		Energy Reduction Target
75	Or	Select

*Choose the design target and select "**View Results**" to display associated energy use for the target.

4. Estimated Design Energy

Use results from energy analysis and enter total estimated energy for the design. Select "**View Results**" to compare Estimated Energy Use to your Target.

Energy Source	Units	Estimated Total Annual Energy Use[2]	Energy Rate ($/Unit)
Electricity - Grid Purchase	MBtu	1088	$
Natural Gas	MBtu	537	$
[Select Energy Source]			$

Clear Form **View Results**

[1]"Target Score" uses the EPA Energy Performance Rating of 1 -100. A project with a score of 75 or higher is eligible for Designed to Earn the ENERGY STAR certification. "Percent Energy Reduction" is the percent reduction of the Design Energy from the median energy consumption of a similar building with the median being the equivalent of a Rating of 50. The energy reduction target is acceptable for establishing Architecture 2030 and AIA 2030 Commitment goals. Note: The percent of electricity and natural gas (displayed at the top of the Results screen) are the fuel mix percentage from DOE-EIA determined by zip code and space type to calculate energy use targets.

[2]"Estimated Total Annual Energy Use" should include all energy for plug, process and other non-regulated loads, including energy generated from occupant and systems schedules and all energy fuel sources used in the design project. Note: Wind and or/solar energy that will be sold back to the grid shouldn't be included in the estimated total annual energy use.

Output page

Results

The design **achieved** a rating of 75 or higher:

APPLY for "Designed to Earn the ENERGY STAR"

View Statement of Energy Design Intent

NOTE: Values are 67% Electricity - Grid Purchase and 33% Natural Gas. The Target & Median Building energy use for this facility are calculated based on fuel mix of input estimated energy use.

Results for Estimated Energy Use			
Energy	**Design**	**Target**	**Median Building**
Energy Performance Rating (1-100)	94	75	50
Energy Reduction (%)	53	26	0
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	110	175	237
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	43	68	92
Total Annual Source Energy (kBtu)	4,196,159	6,650,738	8,992,290
Total Annual Site Energy (kBtu)	1,625,000	2,575,558	3,482,345
~~Total Annual Energy Cost ($)~~	~~$ 35,851~~	~~$ 56,822~~	~~$ 76,828~~
Pollution Emissions			
CO2-eq Emissions (metric tons/year)	183	289	391
CO2-eq Emissions Reduction (%)	53%	26%	0%

Utility costs were not input

Facility Information Edit

GPIC 661
19143
United States

Facility Characteristics Edit	
Space Type	**Gross Floor Area (Sq. Ft.)**
Office	38,000
Total Gross Floor Area	38,000

* The Median Building is equivalent to an EPA Energy Performance Rating of 50.

Estimated Design Energy Edit			
Energy Source	**Units**	**Estimated Total Annual Energy Use**	**Energy Rate ($/Unit)**
Electricity - Grid Purchase	MBtu	1,088	$ 26.520/MBtu
Natural Gas	MBtu	537	$ 13.030/MBtu

Source: Data adapted from DOE-EIA. See EPA Technical Description.

Appendix F: Developed Design & Implementation Phase Energy Analysis Report, Atelier 10

Developed Design & Implementation Phase Energy Analysis Report

Greater Philadelphia Innovation Cluster Building 661

August 1, 2012

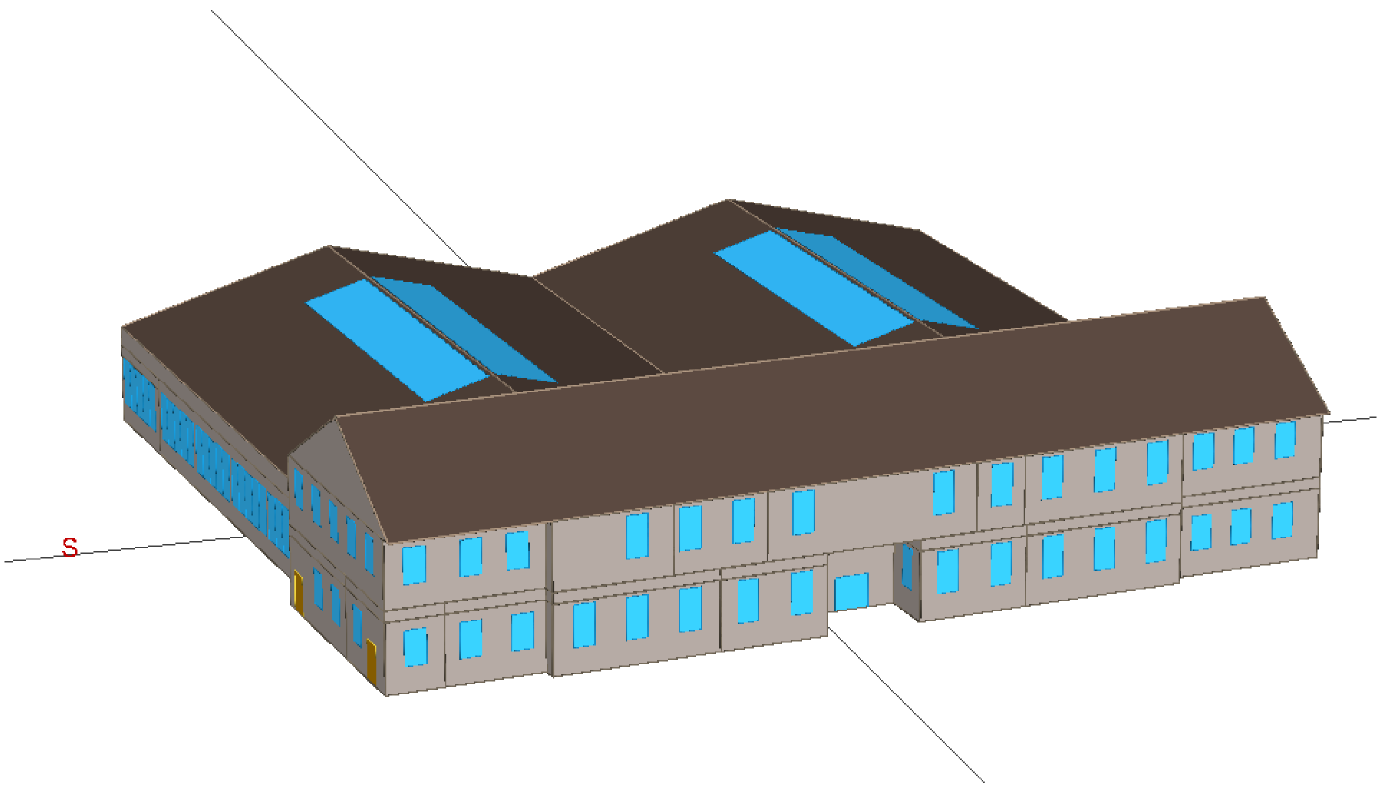


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Table of Contents

Executive Summary

Atelier Ten has conducted a whole building energy analysis for Building 661 of the Energy Efficient Buildings Hub (EEB HUB, formerly GPIC) renovation project at the Detailed Design & Implementation (DD&I) phase. The purpose of this study is to:

- Benchmark the Proposed Design against a reference case, which is in accordance with the minimally compliant ASHRAE 90.1-2007 Appendix G building, in order to assess credits for LEED for New Construction 2009 EAc1.
- Benchmark the Proposed Design against Pennsylvania State University's (PSU) requirement for 30% energy savings compared to ASHRAE 90.1-2007.
- Assess if design meets project goal of being 50% better than a typical comparable building (75th percentile of existing buildings using Energy Star rating system).
- Assess the effectiveness of various potential energy efficiency measures for HVAC, envelope and lighting.

Based on the current design assumptions, the results indicate that the Proposed Design performs 39.8% better in terms of annual energy consumption and 27.6% in terms of annual energy cost relative to the ASHRAE 90.1-2007 Baseline. This meets PSU's goal. The Proposed Design would earn 10 points of 19 possible LEED EA credit 1 points, but if the project achieves 28% energy cost savings then 11 points would be earned. The preliminary Energy Star rating is in the range of 89-92, meeting the project goals of 75 or higher. The Baseline model energy use intensity (EUI) is 67 kBtu/sf-year; the Proposed Design EUI is 40 kBtu/sf-year.

Energy efficiency strategies currently incorporated into the Proposed Design include:

- Existing windows to be replaced with double glazed low-e argon-filled units with thermally broken frames
- Strategic location of higher performance glazing at skylights and south window
- Reasonable window to wall ratio (not over-glazed)
- Insulation (R-20) added to existing walls
- Insulation (R-30) added to existing roof
- Dedicated outdoor air unit with exhaust air energy recovery (enthalpy wheels) & desiccant dehumidification
- Passive and active chilled beams
- Demand controlled ventilation for most spaces
- Efficient condensing boiler and heat recovery chiller
- Variable refrigerant volume system for first floor offices
- Under floor air delivery with displacement diffusers
- Daylight dimming controls in perimeter spaces and high bay central space
- Occupancy sensors in most spaces
- Approx. 32 % reduction in lighting power densities (LPD)

The following options were evaluated in order to test their effect on building energy performance

- Adding external shading to skylights and south windows with VE-12M glass (SHGC: 0.37)
- Adding external shading to skylights and south windows with current Solarban 70XL glass (SHGC: 0.27)
- Solar collectors for domestic hot water with electric heat backup
- Solar collectors for domestic hot water with natural gas backup
- Indirect-direct evaporative cooling at DOAS and/or rooftop units

Adding external shading showed modest annual energy savings in the range of 0.5 to 1.0%, which should be considered alongside factors such as visual comfort, glare, and first cost. The solar hot water provides energy saving of 1.2% and no significant energy cost saving, the main reason for which is the use of electric heat backup which is more costly than to natural gas backup. For comparison, using natural gas backup would provide 1% more energy saving and 0.5% more energy cost saving. Although the savings are modest, the solar hot water system may be included in the project for educational purposes. The option of having indirect-direct evaporative cooling at DOAS and rooftop unit's shows reduction in energy consumption by 0.8% and increase in energy cost saving by 0.5%, but it is not recommended due to the higher maintenance effort and cost. Further investigation and discussion with the design team and client is required to determine the feasibility of incorporating these measures.

The main changes from the Criteria Design phase model issued April 10th to this DD&I phase model are:

- Overall wall construction changed from R-9 to R-20
- Space temperature set points have been changed from 75˚ to 76˚ F for cooling and 72˚ to 70˚ F for heating
- Window to Wall ratio reduced from 21% to 17.5%
- Included higher performance glazing (Solarban 70XL) for south windows and skylight
- Daylighting in high bay labs from the skylights
- Desiccant dehumidification and exhaust air energy recovery added to dedicated outside air unit
- Heat recovery chillers
- Lighting power density reduced by 32%
- Higher equipment power densities (EPD)
- Changes in building occupancy, lighting and equipment schedules
- Server room equipment schedule upated

The graphs below show the previous Criteria Design phase energy model results compared to the current Detailed Design & Implementation phase results.

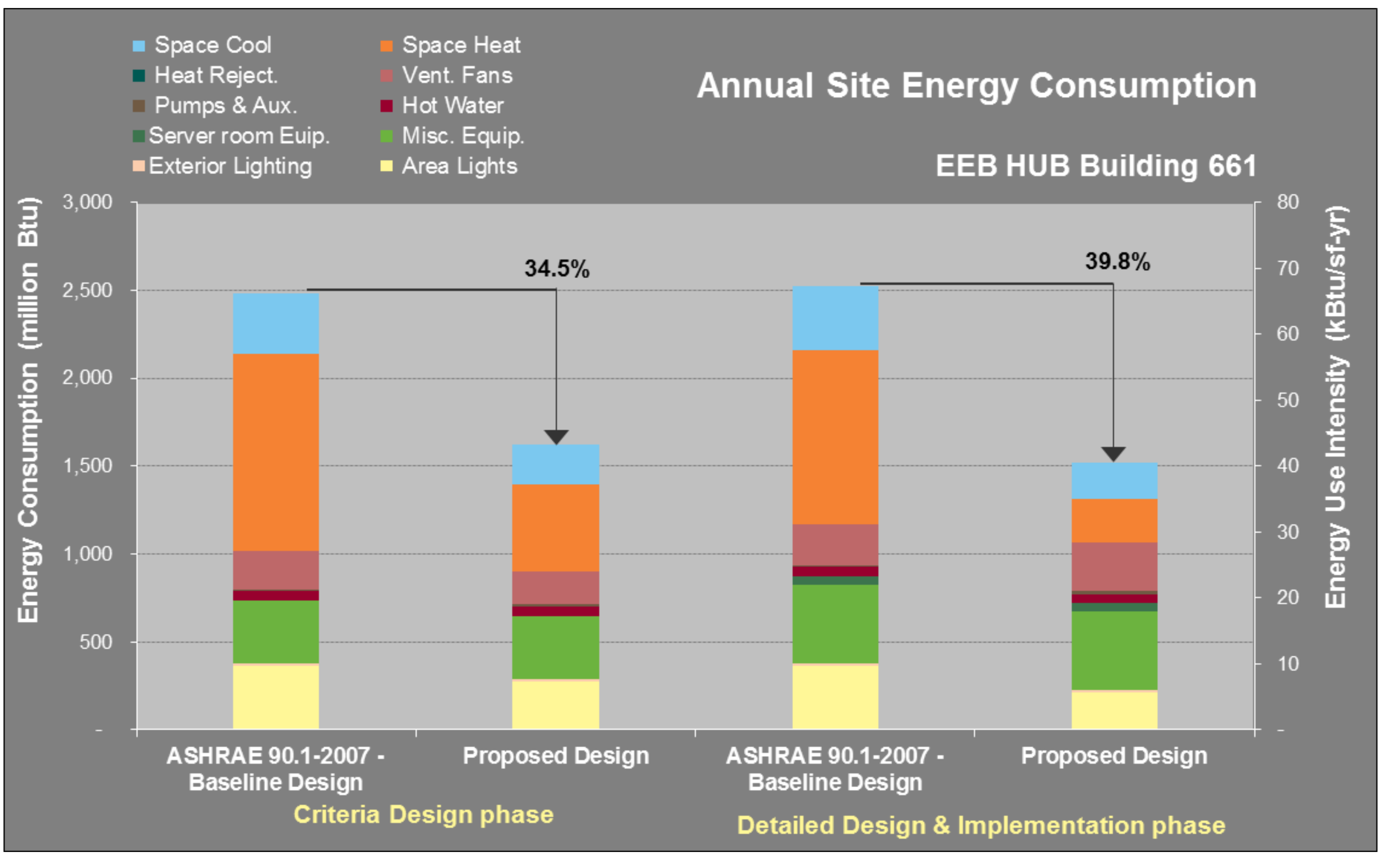


Fig 1 a: Criteria Design vs. Detailed Design & Implementation phase results comparison (energy consumption)

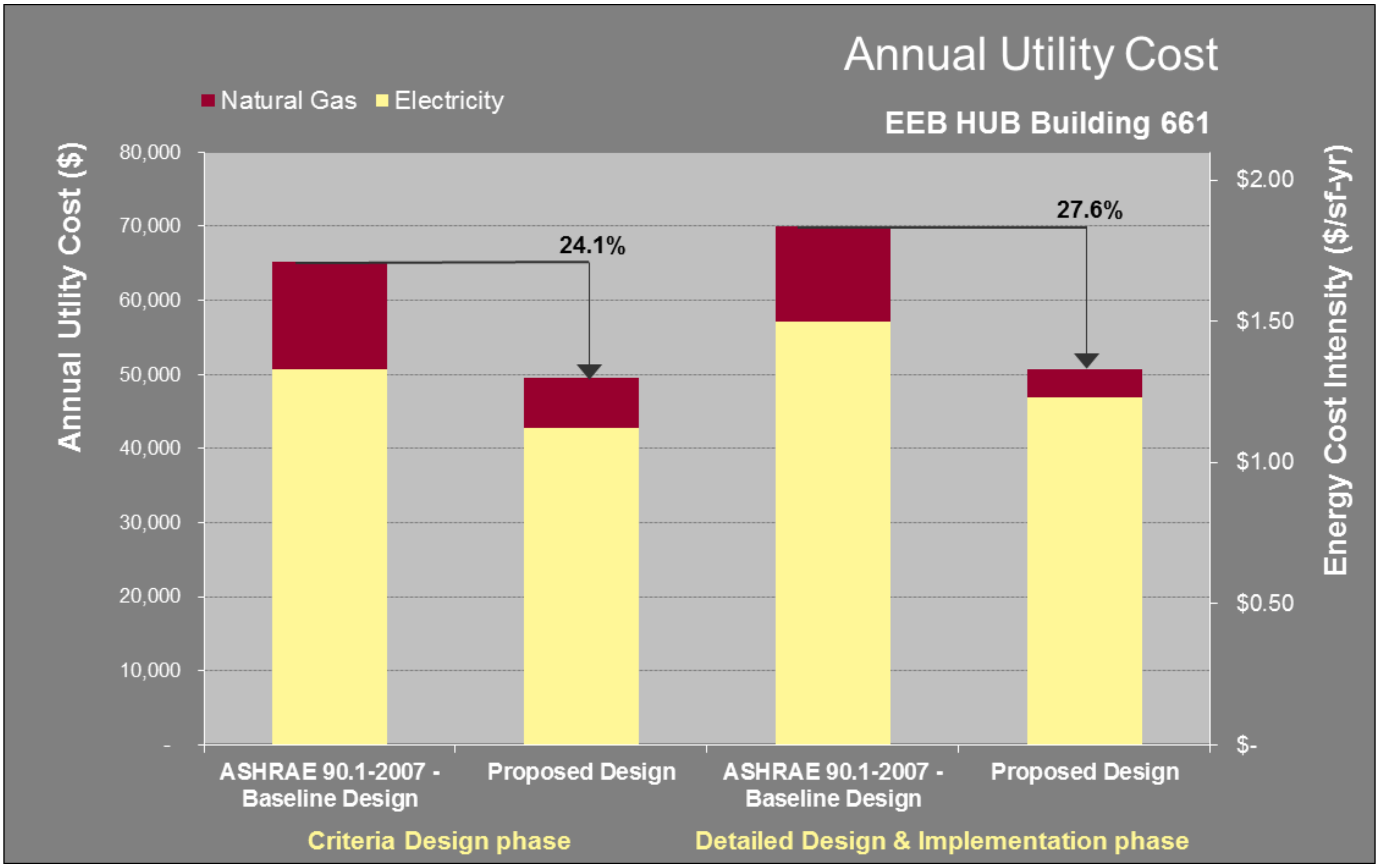


Fig 1 b: Criteria Design vs. Detailed Design & Implementation phase results comparison (energy cost)

The graphs above show the ASHRAE 90.1 baseline energy consumption has gone up slightly in the Detailed Design & Implementation phase; this is because of the higher EPD's considered and the addition of a 24x7 server room equipment schedule. But in terms of percentage energy and cost savings the Detailed Design & Implementation phase model is performing better than the Criteria Design phase model, the main contributors are:

- Reduced lighting power consumption: Lower LPD's and daylighting in highbay areas.
- Much lower heating energy consumption: Better wall insulation, energy recovery wheel and heat recovery chillers.
- Lower cooling energy consumption: Better wall insulation, improved glazing at skylights and south windows.
- The increase in cooling temperature set point by 1˚F and the lower heating temperature set point by 2˚F.

Detailed assumptions for the analysis, including occupancy and internal loads, envelope construction, typical use schedules, and HVAC parameters, are presented at the end of this report and should be reviewed and confirmed by the design team and client.

Introduction

Atelier Ten conducted a Detailed Design & Implementation phase energy analysis for Building 661 of the Energy Efficient Buildings Hub, which is a 2-story building located at the Navy Yard in Philadelphia, Pennsylvania. The building will be undergoing a complete renovation, with a program consisting of approximately 37,925 ft^2 of conditioned area including offices, research spaces, conference rooms, symposium and i-Con lab.

The energy model is based on the May 31, 2012 drawing set and conversations with the design team. The model includes building geometry, construction types, material properties, internal loads, and HVAC systems. Modeling assumptions for operating schedules, set points, lighting power densities, equipment power densities, and HVAC systems and efficiencies were based upon information gathered from the design team. The results will change as the design progresses and as new information is provided in the future.

Atelier Ten created the energy models using eQUEST v3.64 (DOE-2.2 simulation engine). These energy models allow for the comparison of relative energy use throughout the year and assist in identifying specific energy demands for heating, cooling, pumps, fans, lighting, equipment, and hot water. The first energy model, referred to as “Baseline Design”, meets the minimum requirements stipulated in Appendix G of ASHRAE 90.1-2007. The second energy model, referred to as “Proposed Design”, represents the current design. Atelier Ten created additional energy models to evaluate various energy efficiency measures (EEMs) and design alternates considered for this project. At the Detailed Design & Implementation phase, the EEMs are selected to understand the model’s sensitivity or to test items that have space and first cost implications. The scenarios for these models are described below:

- Indirect-direct evaporative cooling at DOAS and RTU’s
- Decrease wall insulation from R-20 to R-13
- Add external shading to skylights and south windows (with VE-12M glazing)
- Add external shading to skylights and south windows (with Solarban 70XL)
- Add solar hot water (with electric heat backup)
- Add solar hot water (with natural gas backup)
- Combined performance of all envelope improvements alone for lifecycle cost analysis

This report begins with a summary of results and then provides discussion about the major energy drivers in the building. Next, the report discusses the results of the analysis with respect to annual energy and utility cost savings for all the measures listed above. This report concludes with recommendations, list of next steps for the design team, and an appendix with the energy model assumptions.

Energy models are representations of the designed building and its future operations. Energy modeling is a design optimization tool which estimates the energy performance of a building. The results from the energy model are accurate in terms of comparative evaluations of energy optimization measures assuming that all the other assumptions remain consistent. However, because energy model results rely on many assumptions about building occupancy patterns, they should not be construed as an absolute prediction of future building energy use.

Summary of Results

The energy model estimates various energy uses throughout the year and identifies specific uses for heating, cooling, pumps, fans, lighting, equipment and hot water. Figure 2 summarizes these end uses in terms of annual site energy (million Btus). Based on the modeling assumptions, the Proposed Design shows an annual energy consumption savings of around 39.8% over an ASHRAE 90.1-2007 Appendix G baseline building.

Heating energy in the Proposed Case is significantly lower compared to the Baseline Building, primarily due to reduced heating loads from the additional wall and roof insulation and improved glazing performance, heat recovery chiller, energy recovery wheel, efficient boiler, and demand controlled ventilation. There is a significant reduction in space cooling energy due to improved glazing, improved envelope insulations, displacement ventilation and chilled beam systems. On the other hand fan energy has gone up considerably because of higher pressure drops required for the various air-side system components (enthalpy wheel, DX cooling coil, chilled water cooling coil, dehumidification wheel, heating coil, reactivation coil) of the DOAS, this is in spite of the fact that the chilled beams and displacement ventilation contribute toward lower fan power consumption. Finally, daylight dimming contributes to lighting savings, as well as cooling savings due to reduced internal gains.

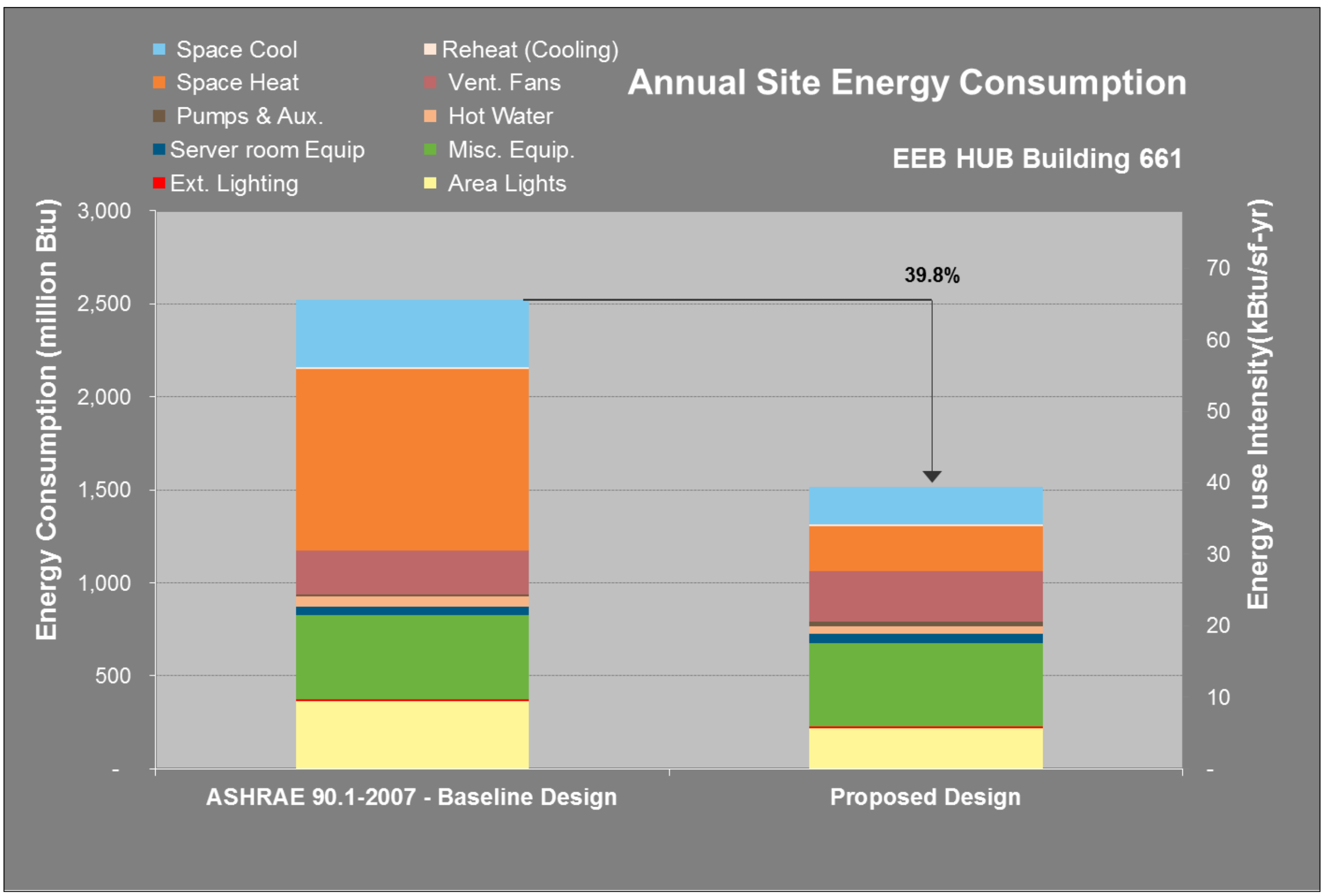


Figure 2: Annual Energy Consumption Comparison

The Proposed Design shows an annual energy cost savings of around 27.6% compared to an ASHRAE 90.1-2007 Appendix G baseline building. Large natural gas savings are achieved through the heating energy reduction, and electricity savings result primarily from cooling and lighting savings. Note that the cost savings percentage (27.6%) is lower than the energy savings percentage (39.8%), this occurs because most of the energy savings comes from reduction in natural gas use, and natural gas has a much lower cost per unit energy than electricity.

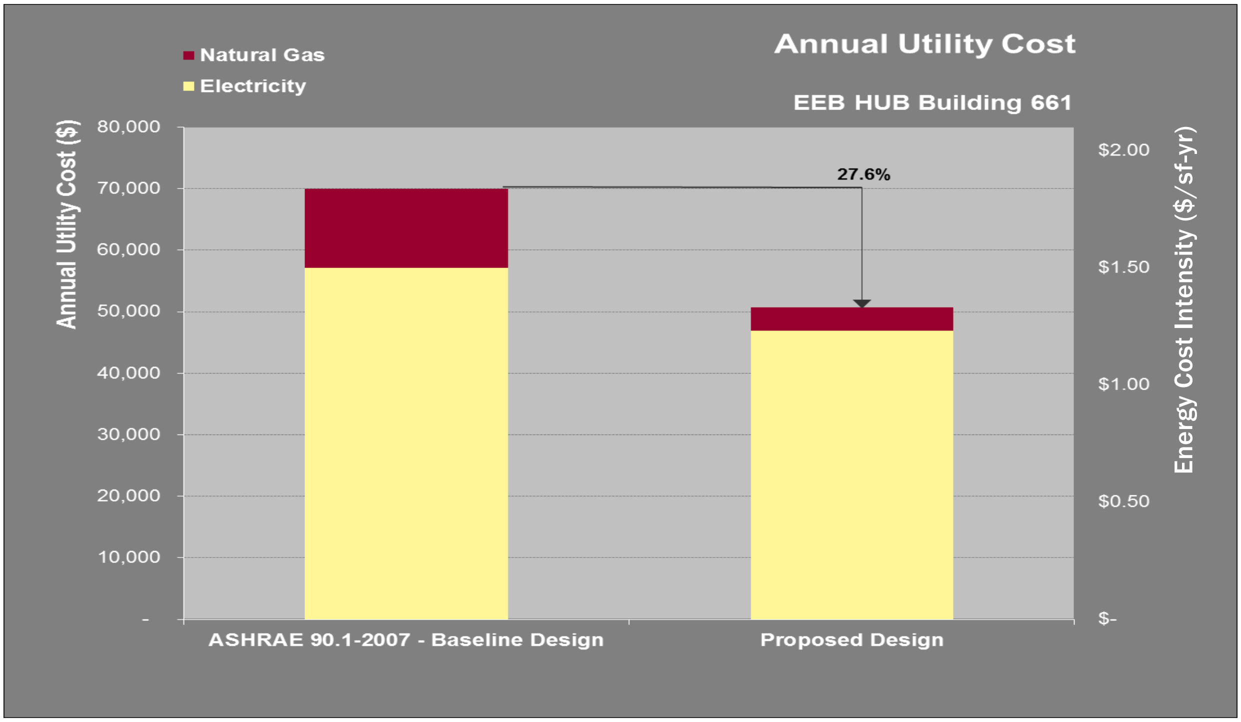


Figure 3: Annual Energy Cost Comparison

The annual CO_2 emission for the proposed building is 27% less as compared to the baseline, the percentage of CO_2 emission is very similar to the energy cost savings because of the lower CO_2 emission rate compared to electricity.

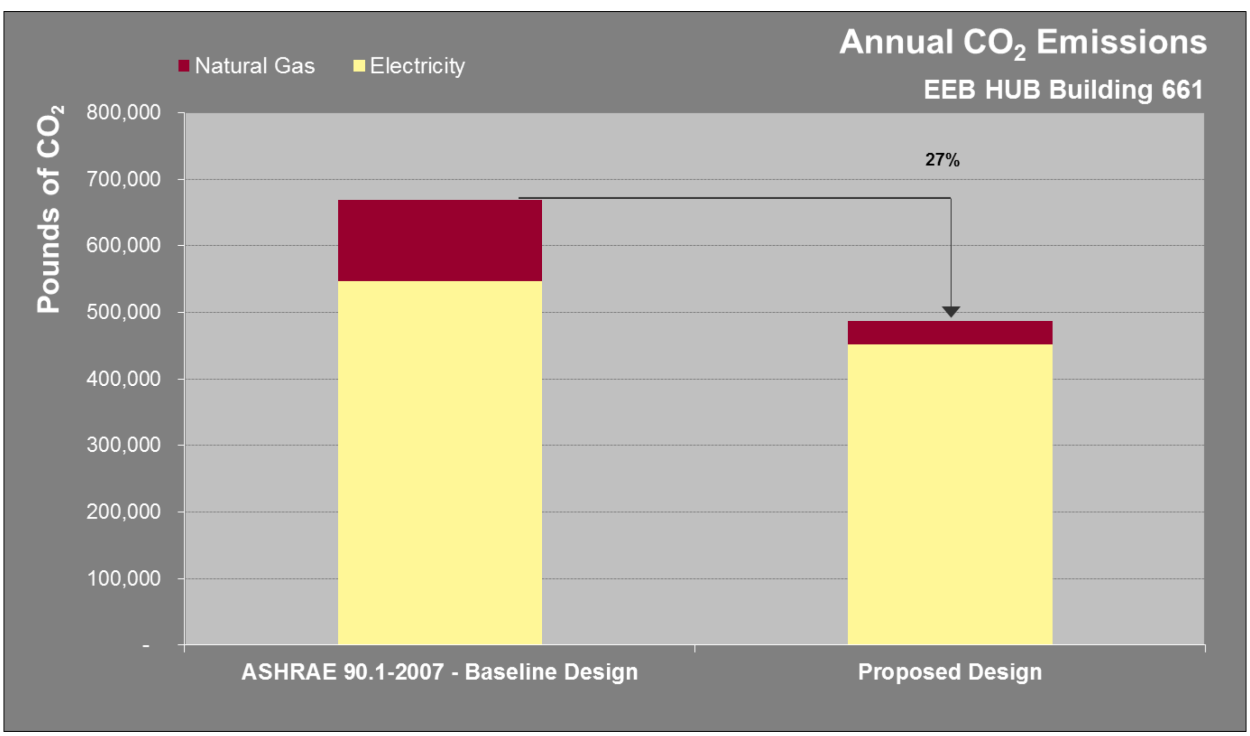


Figure 4: Annual CO_2 emission Comparison

In this energy model, the Proposed Design Case and Baseline Case are currently both assume the same infiltration rate of 0.4 ACH (a very air tight building). In order to take credit for an infiltration rate reduction in the Proposed Design Case, the infiltration rate would need to be measured before and after the renovation. This test may be part of this project's scope, and would match its research intent, but has yet to be confirmed by EEB HUB. It should also be noted that the modeling guidelines in ASHRAE do not provide strict guidelines for modeling improvements in infiltration.

The project team should consider blower door tests before and after the renovation to quantify improved air tightness and take credit for it in the energy model.

Energy efficiency measures

Atelier Ten evaluated three potential energy efficiency measures and tested two reverse EEM's for this phase of the project. Results are shown in Figures 5 and 6.

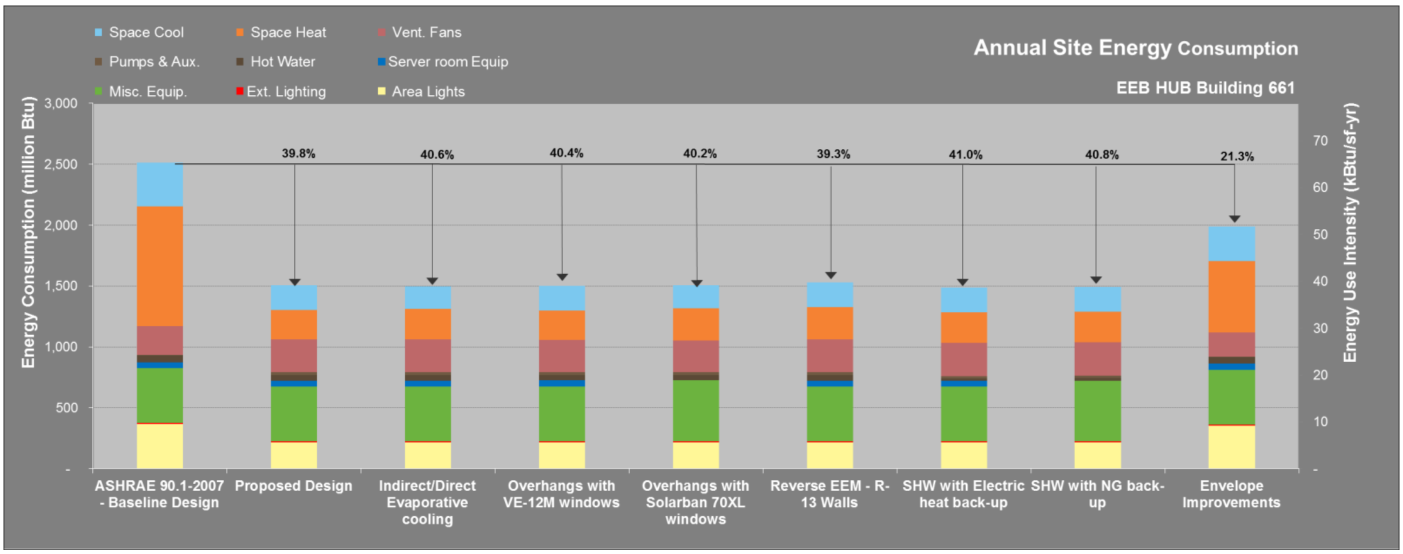


Figure 5: Annual Energy Consumption Comparison (Energy efficiency measures and alternatives)

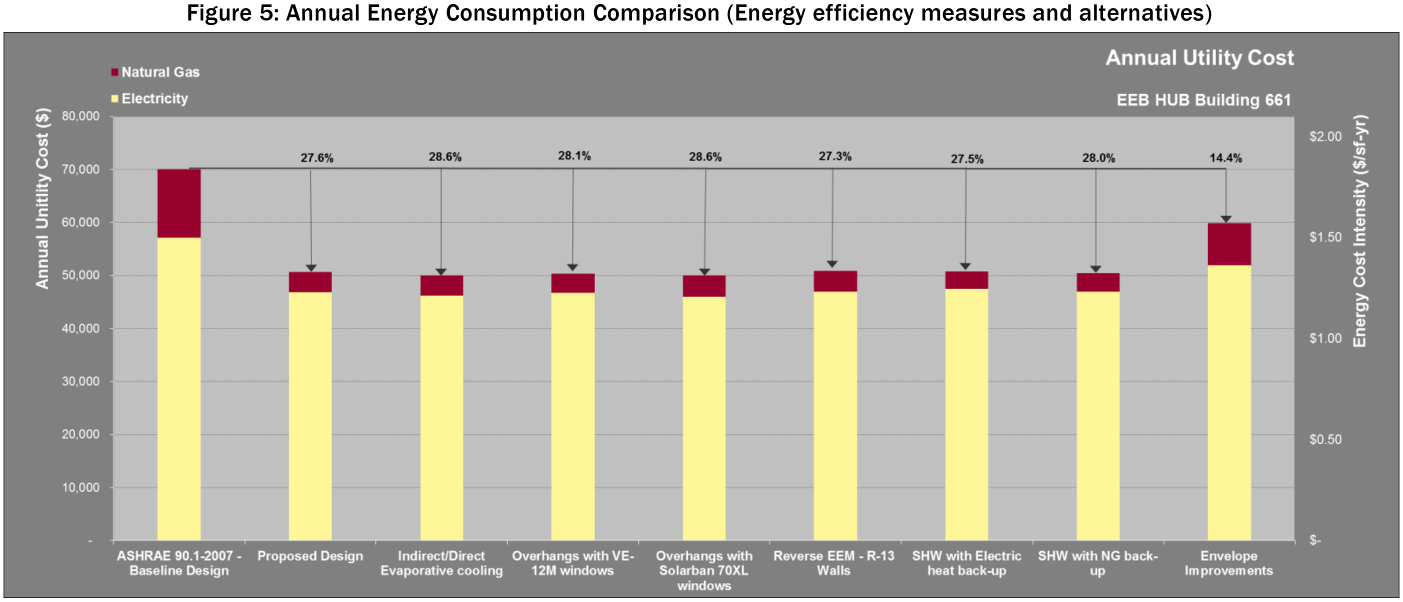


Figure 6: Annual Energy Cost Comparison (Energy efficiency measures and alternatives)

Below is a description of each energy efficiency measure shown in figure 5 and 6. Each energy efficiency measure is added individually to the Proposed Design case, with the exception of the “All Envelope Improvements” case.

Indirect/direct evaporative cooling: Adding indirect-direct evaporative cooling to the DOAS and RTU's reduces the cooling energy consumption, providing 0.8% additional energy saving and 1% additional energy cost saving. Since the entire cooling energy comes from electricity we can see a higher percentage of cost savings. Although we see good results with this addition, having an indirect-direct evaporative cooling in the currently designed DOAS system will require increased maintenance and cleaning so is not recommended.

Decrease total wall assembly from R-20 to R-13: Reducing the total wall assembly from R-20 to R-13 increases energy use by 0.5 % and energy cost by 0.3 %. The higher insulation value is recommended due to accumulated operational cost savings over the long life of the building and thermal comfort benefits.

External shading on skylights and south windows (with lower performing windows): This EEM added a two foot deep overhang to the top of the south windows, and skylight external shading as shown on the Criteria Design set. It shows 0.6% energy savings and 0.5% energy cost savings. There is a minor reduction in cooling energy in spite of the overhangs because of the poorer SHGC of the glazing Viracon VE 1-2M. The savings are due to reduction in heating energy.

Exterior shading on skylights and south windows (with higher performing windows): This EEM had high performing Solarban 70XL windows instead of Viracon VE 1-2M, it showed 0.4% reduction in energy consumption and 1% energy cost reduction due to a considerable reduction in cooling energy consumption and increase in heating energy.

Note that cases with external shading show higher lighting power consumption in the energy model, although this may not be true in operation. Typically, exterior shading allows occupants to leave the interior shades open more often, resulting in electric lighting savings, a phenomenon which is not captured in this energy model.

Solar Hot Water: This EEM was tested with two different scenarios 1) with electric heat back-up 2) with natural gas back-up. The electric heat back-up showed no significant energy cost reduction but about 1.2% additional energy savings. The main reason for this is the electric heating back-up; the higher cost of electricity is off-setting the savings from utilizing solar energy when it is available. In the second scenario we tested the same EEM with natural gas back-up and found additional 1% reduction in energy consumption and 0.4% reduction in cost as compared to the Proposed Case. The percentage energy cost savings is lower than energy savings because the savings is from reduction in natural gas consumption which is less expensive than electricity. The overall savings are low because the energy cost for domestic hot water is just 1% of the total building energy cost. This analysis shows that given the current small domestic hot water use, solar hot water is not sufficient to earn the LEED renewable energy credit, which requires at least 1% energy cost saving from renewable energy source. SHW may be desirable as a demonstration system.

Envelope Improvements: The EEM was requested during conversation about life cycle analysis, and quantifies the energy savings from envelope improvements alone. In this EEM, everything is same as baseline except for the improvement to the envelope (R-20 walls, R-30 roof and better performing glazing). It shows an energy savings of 21.3% and energy cost savings of 14.4% as compared to the baseline. The envelope improvements contribute to over half of the Proposed Case energy savings and energy cost savings.

Energy Star Target Finder

Another goal of the DD&I energy analysis is to assess if design is 50% better than a typical comparable building (75th percentile of existing buildings using Energy Star rating system). This goal was established in the sustainability workshop with the design team and EEB HUB during the Conceptualization Phase in January 2012.

Preliminary Energy Star building 661 DD phase Proposed Design rating is in the range of 89 - 92, which is far better than the target rating of 75. The exact value is sensitive to the inputs like occupancy numbers and building operating hours, so several scenarios were evaluated to establish a likely range.

Atelier Ten also tested the Energy Star rating for the Baseline Case energy model which, under certain occupancy conditions met the target rating of 75. This indicates to the team that perhaps the rating target 75 is not ambitious enough and the teams should discuss increasing the target higher benchmark score.

For reference, a median existing building of this type has a rating of 50. The EPA provides reference targets that are based on the energy consumption of existing buildings, as collected by the U.S. Department of Energy, Energy Information Administration's 2003 Commercial Buildings Energy Consumption Survey (CBECS).

Upon completion, if the project meets or exceeds the target rating of 75, they can apply for “Designed to Earn the ENERGY STAR Certification” and then verify actual performance to earn the “Energy Star Label.”

Please note that the current rating is built upon the current project data and could change based on future project data. The inputs for the Energy Star Target Finder include zip code, program, area, operating hours, workers, number of personal computers, air conditioning, heating, and estimated design energy. For more info on inputs and outputs for the Energy Star Target Finder, please see the Appendix.

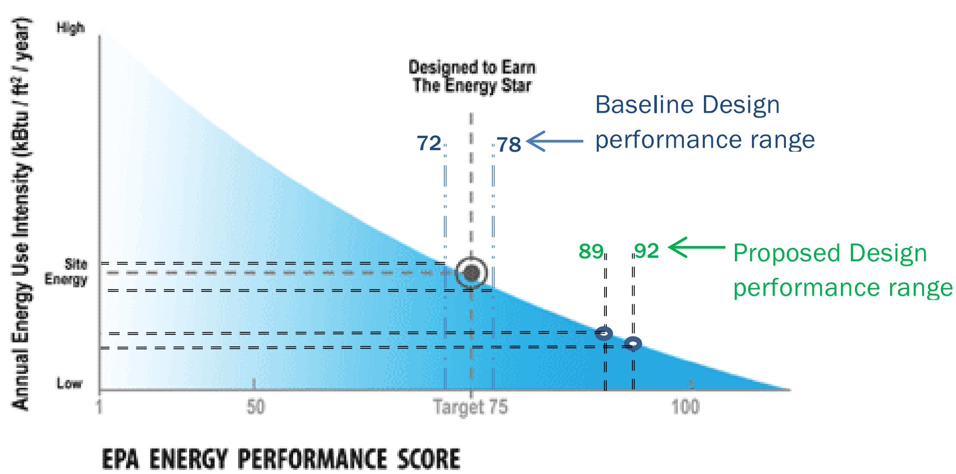


Figure 7: Energy Star Target Finder Graph

Recommendations and Next Steps

Based on the results and analysis the recommendations for this project include:

1. Retain the proposed R-20 walls for the building for continued operational savings over the life of the insulation.
2. Consider visual comfort, glare, and first cost alongside the most energy savings from external shading on the windows and skylights.
3. Consider including solar hot water as a demonstration system although it would not earn points for the LEED On-site Renewable Energy credit.
4. Consider a blower door tests before and after the renovation to quantify improved air tightness and take credit for it in the energy model.

In the next design phase, Atelier Ten will conduct a model to benchmark the final design. Prior to the next model iteration, KT, BBA, and EEB HUB should discuss and record comments on this model and appendix.

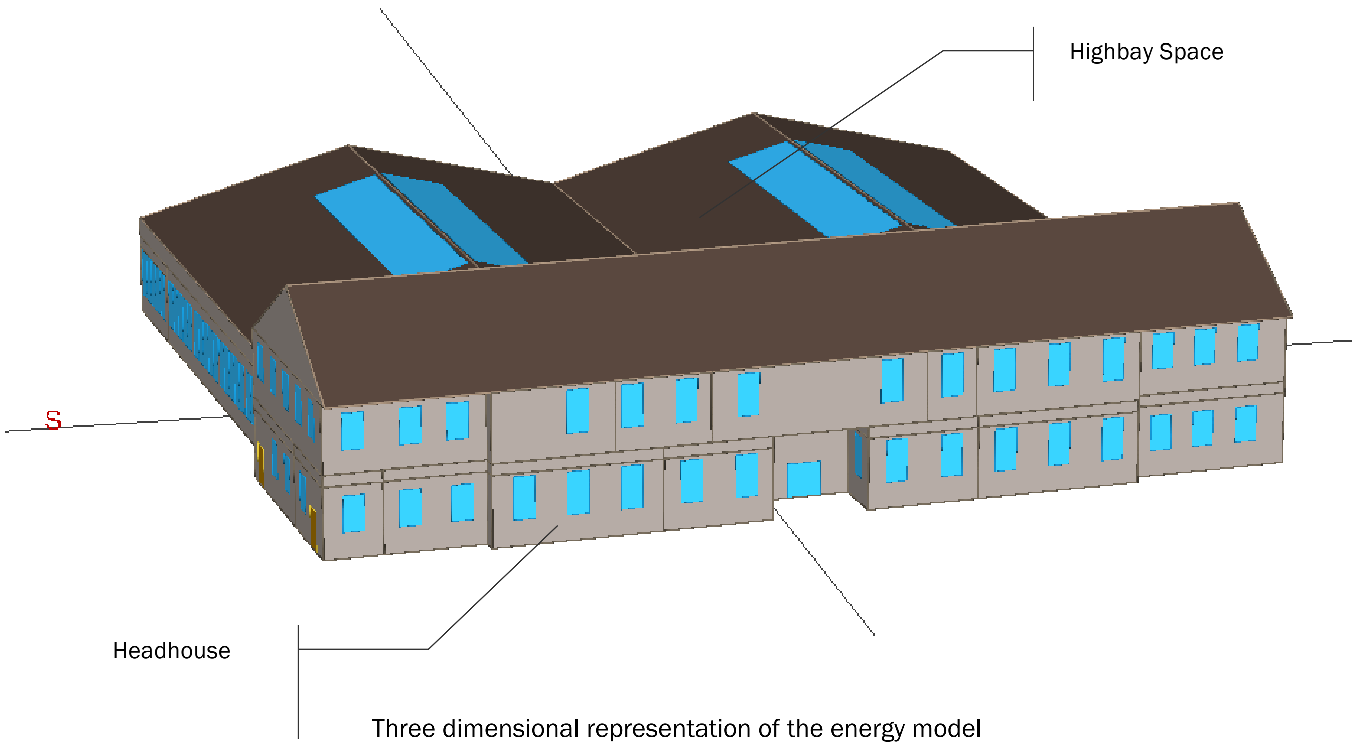
Atelier Ten foresees refinements to several aspects of the model in the next phase, including:

1. Test the impact on varying the number of occupants based on seat count rather than ventilation standards.
2. There is further scope of refinement to the modeled DOAS system, this would require further discussion with the mechanical engineers to understand the design intent and to make all envisaged savings are captured.
3. Refine or test HVAC controls.
4. Clarify with IT consultant if server room equipment consumes less energy at night when the building is unoccupied.

Appendix

Appendix A: General modeling parameters

Analysis Tool: eQUEST (DOE 2.2 Engine) v3.64
Weather File: DOE 2.2 TMY2 weather file for Philadelphia, PA
ASHRAE Climate Zone: 4A
Building Area (as simulated with DOE 2.2): appx. 37,925 gross ft^2
Number of Floors: 2 above grade, mezzanine
Existing Renovation / New Construction: 100% / 0%
Principal Heating Source: Hot Water from Condensing Boilers
Principal Cooling Source: Chilled Water from Air-cooled Chiller



Three dimensional representation of the energy model

Appendix B: Building envelope construction

Building Element	Proposed Design	Baseline Design
Envelope		
Exterior Wall Construction	Typical Wall Construction: 8" Brick 1" Airspace 4" CMU R-10 Spray foam insulation between 16" metal studs 1" continuous insulation Assembly U-Factor: 0.05 Btu/hr-ft^2-°F (R-20)	Existing Wall Construction: 8" Brick 1" Airspace 4" CMU Assembly U-Factor: 0.255 Btu/hr-ft^2-°F (R-4)
Roof Construction	Typical Roof: R-30 continuous insulation Assembly U-Factor: 0.032 Btu/hr-ft^2-°F (R-30)	Existing Roof: Headhouse: R-19 batt insulation (many holes) Assembly U-Factor 0.10 Btu/hr-ft^2-ºF (R-10) Highbay: R-20 insulation above deck Assembly U-Factor 0.048 Btu/hr-ft^2-ºF (R-21)
Slab-on-Grade Construction	Concrete Slab-on-Grade Assembly F-Factor: 0.73 Btu/hr-ft-°F 6" concrete	ASHRAE 90.1-2007 Appendix G Slab-on-Grade Table 5.5-5 Unheated Slab Assembly F-Factor: 0.73 Btu/hr-ft-ºF
Window-to-Wall Ratio	17.5%	13%
Glazing Description (windows and skylights)	Typical Glazing: Double glazed units (VE 1-2M with argon) with thermally broken aluminum frame for East, West and North windows Solarban 70XL with thermally broken aluminum frame for South windows and skylight.	Existing Glazing: Double glazed units with aluminum frame
Glazing U-Factor (windows and skylights)	VE 1-2M: Center-of-Glass: 0.25 Btu/hr-ft^2-°F Solarban 70XL: Center-of-Glass: 0.26 Btu/hr-ft^2-°F	Existing Glazing: Assembly: 0.67 Btu/hr-ft^2-°F
Glazing SHGC (windows and skylights)	VE 1-2 M: 0.37 Solarban 70XL: 0.27	Existing Glazing: 0.71
Glazing VLT (windows and skylights)	VE 1-2 M: 70 % Solarban 70XL: 64 %	Existing Glazing: 80%
Infiltration	0.4 ACH*	0.4 ACH*

*ACH in eQUEST are not described at a certain air pressure. eQUEST simply models a constant air change rate in the perimeter spaces. The conditions of this air match the outdoor air properties from the climate file.

Appendix C: Building occupancy, lighting power density and equipment load

Building Element	Proposed Design	Baseline Design
Lighting		
Interior Lighting Power Density	Offices: 0.7 W/sf Labs: 0.8 W/sf Conference Rooms: 1 W/sf Symposium: 1.1 W/sf Mechanical: 0.8 W/sf Storage: 0.5 W/sf Corridors: 0.5 W/sf Restroom: 0.8 W/sf Lobby: 1 W/sf Lounge: 0.9 W/sf	ASHRAE 90.1-2007 Compliant (Table 9.6.1) Offices/Labs: 1.1 W/sf Conference Rooms: 1.3 W/sf Symposium, iCon Lab: 1.4 W/sf Mechanical: 1.5 W/sf Storage: 0.8 W/sf Corridors: 0.5 W/sf
Daylighting Controls	Continuous daylight dimming controls in perimeter spaces and highbay central area Illuminance target: Office, Labs: 50 fc Meeting rooms: 40 fc Telepresence: 100 fc	None.
Occupancy Sensors	Present in most areas, including offices, lab rooms, conference rooms, storage areas, mechanical rooms (10% LPD credit for spaces with occ. sensors)	In areas required by Section 9.4.1.2 (classrooms, break rooms, conference rooms).
Exterior Lighting Power Density	Same as Baseline Design	ASHRAE 90.1-2007 Compliant
Equipment		
Receptacle Equipment	labs: 1.5 W/sf offices: 1.5 W/sf open area in the high bay: 0.25 W/sf meeting rooms: 2.0 W/sf Icon lab: 1.5 W/sf Symposium: 2 W/sf Server room: 10W/sf	Same as Proposed Design
Occupancy		
Occupant Density	Lab rooms: 100 sf/person Offices: 120 sf/person Conference areas: 30 sf/person i-Con lab: 60 people Symposium: 114 people Server room:	Same as Proposed Design
Building Schedule	See attached occupancy schedules	Same as Proposed Design

Appendix D: Building occupancy, lighting and equipment schedules

The following schedules for occupancy, lighting, and equipment estimate the diversified occupancy and electric usage pattern for different types of spaces for every hour of the year. Schedules are described in the form of percentage of maximum occupancy density (or total occupancy), or percentage of peak lighting and equipment loads in every hour. Please note the lighting schedules listed are the typical uncontrolled lighting schedules and do not reflect the application of lighting controls including occupancy sensors and daylight dimming.

Building 661 is not closed on holidays, so there are no holiday schedules listed.

Weekend occupants will only use Area 1 (the high bay space); Areas 2 and 3 (the head house) will be unoccupied on weekends.

Area 1 Schedule

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
12:00 AM	1:00 AM	0%	0%	2%	2%	6%	6%
1:00 AM	2:00 AM	0%	0%	2%	2%	6%	6%
2:00 AM	3:00 AM	0%	0%	2%	2%	6%	6%
3:00 AM	4:00 AM	0%	0%	2%	2%	6%	6%
4:00 AM	5:00 AM	0%	0%	2%	2%	6%	6%
5:00 AM	6:00 AM	0%	0%	2%	2%	6%	6%
6:00 AM	7:00 AM	5%	0%	10%	2%	25%	6%
7:00 AM	8:00 AM	25%	0%	27%	2%	50%	6%
8:00 AM	9:00 AM	75%	0%	75%	2%	80%	6%
9:00 AM	10:00 AM	90%	0%	90%	2%	90%	6%
10:00 AM	11:00 AM	85%	5%	90%	10%	90%	6%
11:00 AM	12:00 PM	54%	5%	80%	10%	90%	6%
12:00 PM	1:00 PM	54%	5%	80%	10%	90%	6%
1:00 PM	2:00 PM	75%	5%	90%	10%	90%	6%
2:00 PM	3:00 PM	88%	5%	90%	10%	90%	6%
3:00 PM	4:00 PM	90%	5%	90%	10%	90%	6%
4:00 PM	5:00 PM	89%	5%	89%	10%	90%	6%
5:00 PM	6:00 PM	82%	0%	86%	2%	90%	6%
6:00 PM	7:00 PM	66%	0%	76%	2%	84%	6%
7:00 PM	8:00 PM	29%	0%	35%	2%	49%	6%
8:00 PM	9:00 PM	12%	0%	20%	2%	31%	6%
9:00 PM	10:00 PM	5%	0%	10%	2%	6%	6%
10:00 PM	11:00 PM	2%	0%	2%	2%	6%	6%
11:00 PM	12:00 AM	2%	0%	2%	2%	6%	6%

Areas 2 & 3 except Symposium and i-Con Lab

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
12:00 AM	1:00 AM	0%	0%	2%	2%	6%	6%
1:00 AM	2:00 AM	0%	0%	2%	2%	6%	6%
2:00 AM	3:00 AM	0%	0%	2%	2%	6%	6%
3:00 AM	4:00 AM	0%	0%	2%	2%	6%	6%
4:00 AM	5:00 AM	0%	0%	2%	2%	6%	6%
5:00 AM	6:00 AM	0%	0%	2%	2%	6%	6%

Hour		Occupancy		Lighting		Misc. Equipment	
From	**To**	**Weekday**	**Weekend**	**Weekday**	**Weekend**	**Weekday**	**Weekend**
6:00 AM	7:00 AM	5%	0%	10%	2%	25%	6%
7:00 AM	8:00 AM	25%	0%	27%	2%	50%	6%
8:00 AM	9:00 AM	75%	0%	75%	2%	90%	6%
9:00 AM	10:00 AM	90%	0%	90%	2%	90%	6%
10:00 AM	11:00 AM	85%	0%	90%	2%	90%	6%
11:00 AM	12:00 PM	54%	0%	80%	2%	90%	6%
12:00 PM	1:00 PM	54%	0%	80%	2%	90%	6%
1:00 PM	2:00 PM	75%	0%	90%	2%	90%	6%
2:00 PM	3:00 PM	88%	0%	90%	2%	90%	6%
3:00 PM	4:00 PM	90%	0%	90%	2%	90%	6%
4:00 PM	5:00 PM	89%	0%	89%	2%	90%	6%
5:00 PM	6:00 PM	82%	0%	86%	2%	90%	6%
6:00 PM	7:00 PM	66%	0%	76%	2%	84%	6%
7:00 PM	8:00 PM	29%	0%	35%	2%	49%	6%
8:00 PM	9:00 PM	12%	0%	20%	2%	31%	6%
9:00 PM	10:00 PM	5%	0%	10%	2%	6%	6%
10:00 PM	11:00 PM	2%	0%	2%	2%	6%	6%
11:00 PM	12:00 AM	2%	0%	2%	2%	6%	6%

Note that the Symposium is assumed to be fully occupied two times per week.

Symposium Schedule

Hour		Occupancy		Lighting		Misc. Equipment	
From	**To**	**Weekday TR**	**Weekend & MWF**	**Weekday TR**	**Weekend & MWF**	**Weekday TR**	**Weekend & MWF**
12:00 AM	1:00 AM	0%	0%	2%	2%	6%	6%
1:00 AM	2:00 AM	0%	0%	2%	2%	6%	6%
2:00 AM	3:00 AM	0%	0%	2%	2%	6%	6%
3:00 AM	4:00 AM	0%	0%	2%	2%	6%	6%
4:00 AM	5:00 AM	0%	0%	2%	2%	6%	6%
5:00 AM	6:00 AM	0%	0%	2%	2%	6%	6%
6:00 AM	7:00 AM	0%	0%	2%	2%	6%	6%
7:00 AM	8:00 AM	25%	0%	25%	2%	25%	6%
8:00 AM	9:00 AM	90%	0%	90%	2%	45%	6%
9:00 AM	10:00 AM	90%	0%	90%	2%	45%	6%
10:00 AM	11:00 AM	90%	0%	90%	2%	45%	6%
11:00 AM	12:00 PM	90%	0%	80%	2%	45%	6%
12:00 PM	1:00 PM	90%	0%	80%	2%	45%	6%
1:00 PM	2:00 PM	90%	0%	90%	2%	45%	6%
2:00 PM	3:00 PM	90%	0%	90%	2%	45%	6%
3:00 PM	4:00 PM	90%	0%	90%	2%	45%	6%
4:00 PM	5:00 PM	90%	0%	90%	2%	45%	6%
5:00 PM	6:00 PM	0%	0%	2%	2%	6%	6%
6:00 PM	7:00 PM	0%	0%	2%	2%	6%	6%
7:00 PM	8:00 PM	0%	0%	2%	2%	6%	6%
8:00 PM	9:00 PM	0%	0%	2%	2%	6%	6%
9:00 PM	10:00 PM	0%	0%	2%	2%	6%	6%
10:00 PM	11:00 PM	0%	0%	2%	2%	6%	6%
11:00 PM	12:00 AM	0%	0%	2%	2%	6%	6%

The i-Con lab is assumed to be fully occupied once per day for 4 hours per day.

i-Con lab Schedule

Hour		Occupancy			Lighting			Misc. Equipment		
From	To	Weekday MWF	Weekday TR	Weekend	Weekday MWF	Weekday TR	Weekend	Weekday MWF	Weekday TR	Weekend
12:00 AM	1:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
1:00 AM	2:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
2:00 AM	3:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
3:00 AM	4:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
4:00 AM	5:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
5:00 AM	6:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
6:00 AM	7:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
7:00 AM	8:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
8:00 AM	9:00 AM	90%	0%	0%	90%	2%	2%	45%	6%	6%
9:00 AM	10:00 AM	90%	0%	0%	90%	2%	2%	45%	6%	6%
10:00 AM	11:00 AM	90%	0%	0%	90%	2%	2%	45%	6%	6%
11:00 AM	12:00 PM	90%	0%	0%	90%	2%	2%	45%	6%	6%
12:00 PM	1:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
1:00 PM	2:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
2:00 PM	3:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
3:00 PM	4:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
4:00 PM	5:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
5:00 PM	6:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
6:00 PM	7:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
7:00 PM	8:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
8:00 PM	9:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
9:00 PM	10:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
10:00 PM	11:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
11:00 PM	12:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%

Server room operates 24/7 and is served by its own split system. The server room has a very low occuoancy and Lighting power density.

Server Schedule

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
12:00 AM	1:00 AM	0%	0%	5%	5%	50%	50%
1:00 AM	2:00 AM	0%	0%	5%	5%	50%	50%
2:00 AM	3:00 AM	0%	0%	5%	5%	50%	50%
3:00 AM	4:00 AM	0%	0%	5%	5%	50%	50%
4:00 AM	5:00 AM	0%	0%	5%	5%	50%	50%
5:00 AM	6:00 AM	0%	0%	5%	5%	50%	50%
6:00 AM	7:00 AM	0%	0%	5%	5%	50%	50%
7:00 AM	8:00 AM	60%	0%	70%	5%	70%	50%
8:00 AM	9:00 AM	80%	0%	90%	5%	70%	50%
9:00 AM	10:00 AM	90%	0%	90%	5%	80%	50%
10:00 AM	11:00 AM	75%	0%	90%	5%	80%	50%

11:00 AM	12:00 PM	50%	0%	90%	5%	100%	50%
12:00 PM	1:00 PM	50%	0%	90%	5%	100%	50%
1:00 PM	2:00 PM	75%	0%	90%	5%	100%	50%
2:00 PM	3:00 PM	90%	0%	90%	5%	100%	50%
3:00 PM	4:00 PM	90%	0%	90%	5%	100%	50%
4:00 PM	5:00 PM	90%	0%	90%	5%	100%	50%
5:00 PM	6:00 PM	80%	0%	90%	5%	80%	50%
6:00 PM	7:00 PM	60%	0%	90%	5%	80%	50%
7:00 PM	8:00 PM	20%	0%	90%	5%	80%	50%
8:00 PM	9:00 PM	0%	0%	5%	5%	70%	50%
9:00 PM	10:00 PM	0%	0%	5%	5%	70%	50%
10:00 PM	11:00 PM	0%	0%	5%	5%	60%	50%
11:00 PM	12:00 AM	0%	0%	5%	5%	50%	50%

Appendix E: HVAC system parameters

The building is served by three different system types. Spaces in the high bay area (Area 1) are served by 4-pipe passive and active chilled beams and a dedicated outdoor air (DOA) unit with desiccant dehumidification and an enthalpy wheel. Mezzanine spaces in the high bay have under floor air distribution with fan coil units. Chilled water is provided by an air-cooled heat recovery chiller and hot water by a condensing boiler. Most spaces in the headhouse (Area 2) are served by a packaged rooftop unit with DX cooling and gas furnace heating, with underfloor air distribution on the second floor. Offices on the first floor of the headhouse (Area 3) are served by variable refrigerant volume fan coil units with natural ventilation. Areas 1 and 2 have perimeter radiator hot water heating (fin tube convectors).

Design Conditions

The chart below show interior space design conditions:

Space	Heating temp °F	Cooling temp °F	High RH %	Low RH %
General Areas	Occupied: 70 Unoccupied: 55	Occupied: 76 Unoccupied: 85	Area 1: occupied & unoccupied: 50% Areas 2 and 3: no maximum RH	0%

Description of the Proposed Building and Baseline Building System Parameters

The chart below describes the HVAC modeling assumptions for the Proposed and Baseline Building models.

Building Element	Proposed Design	Baseline Design
Mechanical Systems		
Primary HVAC System Type	Area 1 (high bay spaces & mezzanine): Dedicated outdoor air unit with desiccant dehumidification to meet ventilation requirements and latent loads. Area 2 (headhouse): Packaged VAV rooftop units with DX cooling and gas furnace heating. Area 3 (headhouse offices): Variable refrigerant volume units with natural ventilation.	ASHRAE 90.1-2007 Appendix G System Type 5: Packaged VAV with reheat One System per Floor
Other HVAC System Type	Area 1: Active and passive chilled beams provide sensible cooling and radiator hot water heating in high bay areas. Fan coil units provide heating and sensible cooling for mezzanine area. Area 2 (headhouse): Radiator hot water heating in perimeter zones. VAV terminal boxes for 1st Floor zones identified as Area 2 Server rooms: Packaged Variable volume variable temperature system	System Type 3: Packaged Rooftop Air conditioner Serving server room
Air Distribution	Overhead mixed distribution for most spaces.	Overhead Mixed

	Air distribution from floor diffusers for 2nd floor mezzanine only. Under floor air plenum with displacement diffusers 2nd floor headhouse, iCon lab and symposium.	
Air-Side Cooling		
Minimum Supply Temperature	Area 1 including mezzanine: 65˚F Area 2 second floor: 65˚F Area 2 first floor: 57˚F	55°F
Cooling Source	Chilled water for chilled beams and DOAS; DX cooling for packaged VAV rooftop units	Same as Proposed
Supply Air Temperature Control	Reset higher by 5°F under minimum cooling load conditions	Reset higher by 5°F under minimum cooling load conditions
DX Efficiency	Area 2 Packaged RTUs: 12 EER IPLV: 14.5 Area 3 VRF system: 3.7 COP	9.3 EER
Air-Side Heating		
Maximum Supply Temperature	85°F	90°F
Heat Source	Hot Water for fin tube convectors at perimeter and DOAS. Recovered heat from heat recovery chillers fed in to the hot water loop for DOAS post heating coil and VAV terminal heating coils Gas furnace for packaged VAV rooftop unit	Hot Water
Zone Heating	VRV, fan coils, fin tube convectors at perimeter except single offices	VAV terminal reheat
Heating Efficiency	Gas furnace: 80% VRF system: 4.1 COP (Input to eQuest)*.	80%
Outdoor Air		
Design Ventilation Rates	ASHRAE 62.1-2007 minimum rates: Area 1: DOAS: 4,300 cfm Area 2 system: Ventilation Total: 1,450 cfm RTU 1: 350 cfm RTU 2: 750 cfm RTU 3: 350 cfm Area 3 system: Naturally ventilated	Same as Proposed Design
Air-side Economizer Cycle	Area 2 system has drybulb economizer, high limit 65°F (includes maintaining space return humidity setpoints)	None (not required).
Heat Recovery	Area 1: 75% latent & sensible Area 2: 70% latent & sensible	None (not required).
Demand Control Ventilation	Carbon dioxide sensors in most spaces modulates outdoor air based on occupancy	Symposium space
Fan Power and Flow		
Fan Power	DOAS: 7.09” w.g. supply, 3.58” w.g. return RTUs: 1.17” w.g. VRF Fan coil units: 1.0” w.g.	ASHRAE 90.1-2007 Appendix G fan power

Minimum Flow Ratio (supply VFD fan reduction limit)	Area 1 System: Primary airflow to meet ventilation requirements. Lower limit is 30% Area 2 System: 30%	0.4 cfm/sf
Minimum flow at terminal boxes from RTU 3	30%	
Water-Side Cooling		
Chiller Type	Air-cooled chiller with heat recovery	N/A
Chiller Efficiency	0.3749 EIR for cooling only 0.2132 EIR at heat recovery mode	N/A
Chilled Water (CHW) Loop	Low temp loop: 43°F supply / 58°F return Plate & frame heat exchangers between loops Passive & active chilled beam loop: 60°F supply / 63°F return	N/A
CHW Loop Temp Reset Parameters	No chiller reset (always at 43) Chilled beam loop reset up to 60° or 65˚ F based on dewpoint	Same as Proposed Design
CHW Loop Configuration	Variable primary flow	Constant primary / variable secondary
Primary CHW Pump Speed Control	Variable speed drive	Variable speed drive
Water-Side Heating		
Boiler Type	Condensing Boiler – To DOAS heating Coil, FCU's, VAV reheat and fin tube convectors at perimeter	Natural Draft Boiler
Boiler Efficiency	92%	80%
Hot Water Loop	160°F supply / 110°F return	180°F supply / 130°F return
HW Loop Temp Reset Parameters	Reset down based on OA temperature	Reset down based on OA temperature
HW Loop Configuration	Variable primary	Variable primary
Pump description	Primary, secondary VFD pumps on boiler loops	
Domestic Water Heating		
DHW Equipment Type	Natural gas	Same as Proposed Design
DHW Flow	0.4 GPM	Same as Proposed Design
DHW Efficiency	80%	80%
Temperature Controls	120°F distribution temperature	Same as Proposed Design

***COP of the VRF system reduces with lower O/A temperature**

Appendix F: Utility Rates

Utility rates used in the energy model are listed below. Based on emails received March 16, 2012 and discussion that these rates are representative for the region.

Electricity (PECO):

$0.1108 / kWh
$4.96/kW
$16.41/month

Natural Gas (Philadelphia Gas Works):

$1.22 / therm
$18.00/month

Appendix G: Energy efficiency measure assumptions

Energy Efficiency Measure	Description
All envelope improvements on baseline model	This EEM tests the contribution of the envelope improvements alone. It includes all envelope improvements and the minimally ASHRAE 90.1-2007 compliant HVAC and lighting systems.
HVAC: Indirect-Direct Evaporative cooling	This EEM includes indirect-direct evaporative cooling in the currently designed DOAS and the RTU's. The indirect-direct evaporative cooling component is added to the existing DOAS and RTU's in the energy model.
Glazing performance/ shading on skylight & south window	This EEM tests the effectiveness of having external shading on south windows and skylights. The overhangs on windows are at parallel to the ground and 2 ft. deep. The shading on the skylights is in the form of discrete fins parallel to the floor. This EEM had been tested with two different scenarios, 1. Better performing Solarban 70XL glazing on south windows and skylights. 2. VE-12 M glazing on south windows and skylights.
Solar hot water	This EEM includes solar hot water for domestic water supply. The solar collectors considered are of Solene make, "Aurora" type flat plate type collectors. No. of collectors: 10 Slope: 40 degrees facing south This EEM has also been tested with two different scenarios, 1. With Electric heat backup 2. With Natural gas backup
Reduce wall assembly to R-13	This is a reverse EEM to test the difference in savings by changing the R-20 walls to R-13 walls. In this EEM the overall wall R-value has been changed from R-20 to R-13.

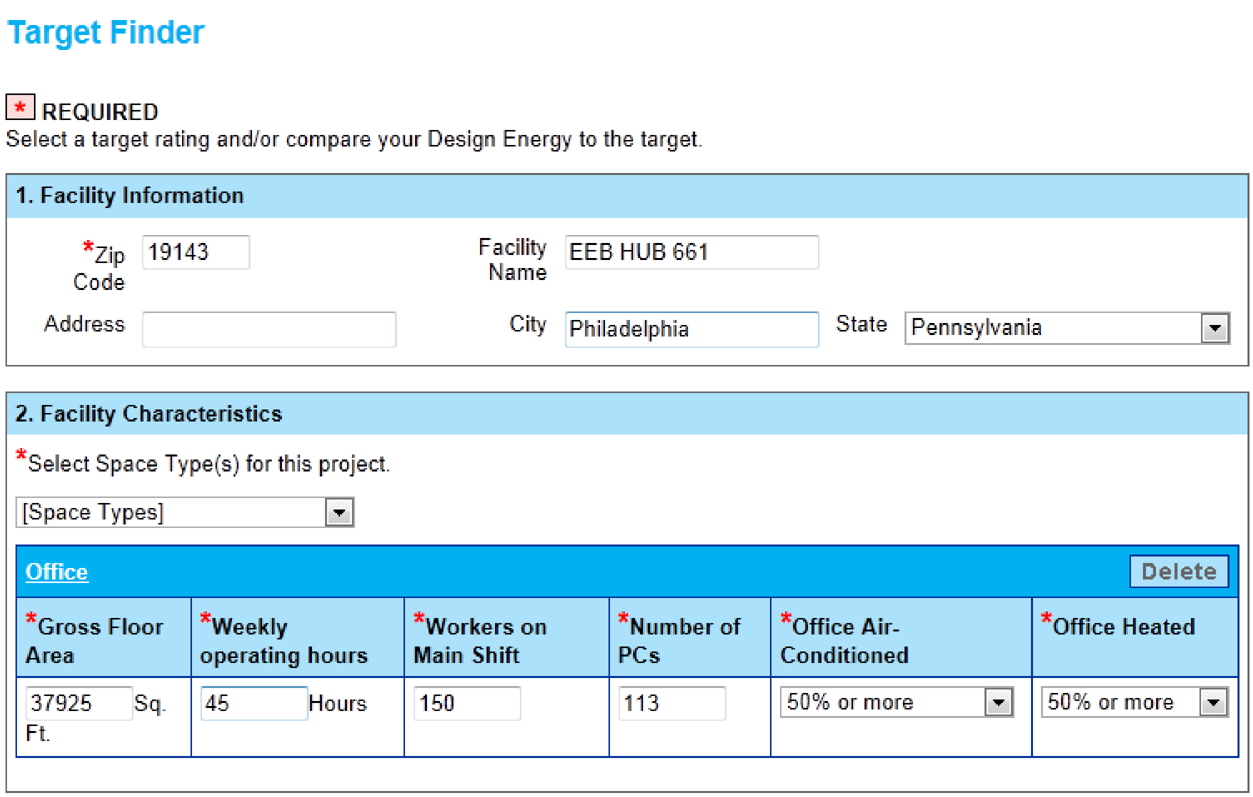
Atelier Ten analyst: JP
Report reviewed by: MT/WKM

Appendix H: Energy Star Target Finder Assumptions and Results

Table of different scenarios evaluated in Energy Star Target Finder

	Occupancy (Nos)	Operating hours (per week)	Number of PC's	EPA energy performance score
Case 1	200	40	91	89
Case 2	250	40	113	91
Case 3	250	45	113	92
Case 4	150	45	113	91
Case 5	150	40	113	91
Case 6	113	55	107	92
Case 7	150	55	113	93

Sample Input Page



3. The Target[1]

Target Rating | Energy Reduction Target

75 Or Select

*Choose the design target and select "**View Results**" to display associated energy use for the target.

4. Estimated Design Energy

Use results from energy analysis and enter total estimated energy for the design. Select "**View Results**" to compare Estimated Energy Use to your Target.

Energy Source	Units	Estimated Total Annual Energy Use[2]	Energy Rate ($/Unit)
Electricity - Grid Purchase	MBtu	1225	$ /MBtu
Natural Gas	MBtu	293	$ /MBtu
[Select Energy Source]			$ /

Clear Form | View Results

[1]"Target Score" uses the EPA Energy Performance Rating of 1 -100. A project with a score of 75 or higher is eligible for Designed to Earn the ENERGY STAR certification. "Percent Energy Reduction" is the percent reduction of the Design Energy from the median energy consumption of a similar building with the median being the equivalent of a Rating of 50. The energy reduction target is acceptable for establishing Architecture 2030 and AIA 2030 Commitment goals. Note: The percent of electricity and natural gas (displayed at the top of the Results screen) are the fuel mix percentage from DOE-EIA determined by zip code and space type to calculate energy use targets.

[2]"Estimated Total Annual Energy Use" should include all energy for plug, process and other non-regulated loads, including energy generated from occupant and systems schedules and all energy fuel sources used in the design project. Note: Wind and or/solar energy that will be sold back to the grid shouldn't be included in the estimated total annual energy use.

Output page

Results

higher:

APPLY for "Designed to Earn the ENERGY STAR"

NOTE: Values are 81% Electricity - Grid Purchase and 19% Natural Gas. The Target & Median Building energy use for this facility are calculated based on fuel mix of input estimated energy use.

View Statement of Energy Design Intent

Results for Estimated Energy Use			
Energy	**Design**	**Target**	**Median Building**
Energy Performance Rating (1-100)	91	75	50
Energy Reduction (%)	48	26	0
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	116	164	222
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	40	57	76
Total Annual Source Energy (kBtu)	4,398,271	6,213,802	8,401,520
Total Annual Site Energy (kBtu)	1,518,000	2,144,604	2,899,664
~~Total Annual Energy Cost ($)~~	~~$ 36,305~~	~~$ 51,291~~	~~$ 69,349~~
Pollution Emissions			
CO2-eq Emissions (metric tons/year)	189	267	361
CO2-eq Emissions Reduction (%)	48%	26%	0%

Utility costs were not input

Facility Information Edit

EEB HUB 661
Philadelphia , PA 19143
United States

Facility Characteristics	Edit
Space Type	**Gross Floor Area (Sq. Ft.)**
Office	37,925
Total Gross Floor Area	37,925

* The Median Building is equivalent to an EPA Energy Performance Rating of 50.

Estimated Design Energy			Edit
Energy Source	**Units**	**Estimated Total Annual Energy Use**	**Energy Rate ($/Unit)**
Electricity - Grid Purchase	MBtu	1,225	$ 26.520/MBtu
Natural Gas	MBtu	293	$ 13.030/MBtu

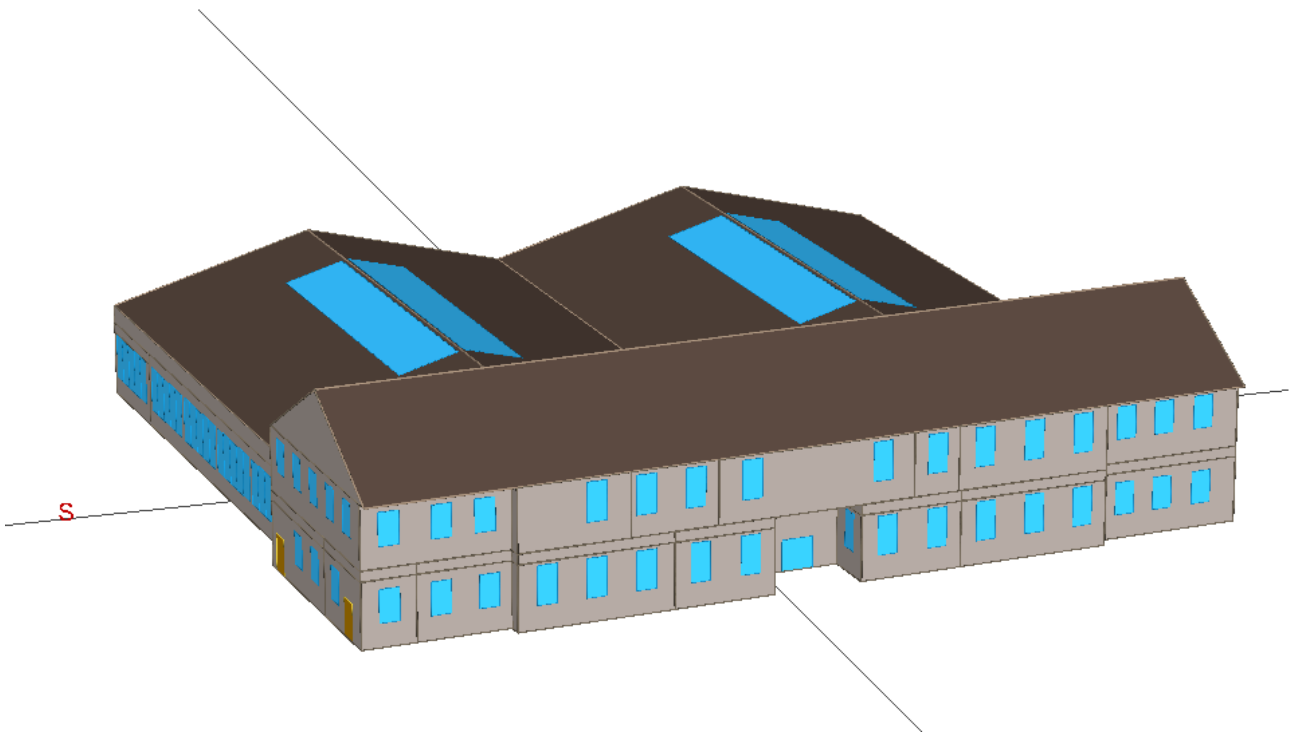
Source: Data adapted from DOE-EIA. See EPA Technical Description.

Appendix G: Developed Design & Implementation Phase Final Energy Analysis Report, Atelier 10

Developed Design & Implementation Phase Final Energy Analysis Report

Greater Philadelphia Innovation Cluster Building 661

October 11, 2012



atelier ten

Environmental Design Consultants + Lighting Designers

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Executive Summary

Atelier Ten has conducted a whole building energy analysis for Building 661 of the Energy Efficient Buildings Hub (EEB HUB, formerly GPIC) renovation project at the end of Detailed Design & Implementation (DD&I) phase. The purpose of this study is to:

- Benchmark the Proposed Design against a reference case, which is in accordance with the minimally compliant ASHRAE 90.1-2007 Appendix G building, in order to assess credits for LEED for New Construction 2009 EAc1.
- Benchmark the Proposed Design against Pennsylvania State University's (PSU) requirement for 30% energy savings compared to ASHRAE 90.1-2007.
- Assess if design meets project goal of being 50% better than a typical comparable building (75th percentile of existing buildings using Energy Star rating system).

Based on the current design assumptions, the results indicate that the Proposed Design performs 42.9% better in terms of annual energy consumption and 32.6% in terms of annual energy cost relative to the ASHRAE 90.1-2007 Baseline. This meets PSU's goal. The Proposed Design would earn 13 points of 19 possible LEED EA credit 1 points.

Atelier Ten would like to propose an exceptional (atypical) calculation method to the US Green Building Council (USGBC) to take credit for the building's improved airtightness. If the infiltration reduction credit is approved by USGBC, it is estimated that the project can achieve up to 38.7% energy cost savings, earning 16 LEED EAc1 points. Note the savings are also dependent on the final envelope tightness to be determined by blower door test results at the end of construction.

The project's current Energy Star rating is in the range of 94-97, meeting the project goals of 75 or higher. The Baseline Design energy use intensity (EUI) is 71 kBtu/sf-year; the Proposed Design EUI is 40 kBtu/sf-year.

Energy efficiency strategies currently incorporated into the Proposed Design include:

- Existing windows to be replaced with double glazed low-e argon-filled units with thermally broken frames
- Strategic location of higher performance glazing at South skylights and high bay south windows
- Reasonable window to wall ratio (not over-glazed – 17.8% WWR)
- Insulation added to existing walls (overall assembly R-24)
- Insulation added to existing roof (overall assembly R-30)
- Dedicated outdoor air (DOA) unit with exhaust air energy recovery (enthalpy wheels) & desiccant dehumidification
- Passive and active chilled beams
- Demand controlled ventilation for most spaces
- High efficiency condensing hot water boiler
- Efficient condensing domestic hot water boiler
- Heat recovery chiller providing regenerative heating and reheat during cooling season
- Variable refrigerant volume system for first floor offices
- Under floor air delivery with displacement diffusers
- Daylight dimming controls in perimeter spaces and high bay central space
- Rooms divided in to multiple zones with vacancy sensor lighting control in each zone
- Approx. 8.5 % reduction in lighting power densities (LPD)
- Manual interior shades below skylight (not considered in energy model)
- Trees on East and South side of the building to prevent glare and to act as exterior shade

The main changes from the preliminary Developed Design and implementation phase model and the current final Developed Design and Implementation model are:

- The envelope infiltration rate changed from 0.1 cfm/sf (very air tight building) to 0.4 cfm/sf for Baseline and Proposed Designs. And the actual envelope infiltration rate data has been used for a second baseline building and compared against better target infiltration rates
- The current model has a LPD reduction of 8.5% compared to 32% considered in the preliminary model
- DX cooling removed from DOA unit (now the system has 100% chilled water cooling)
- The revised fan power for RTU's, FCU's and VRV's are lower than the preliminary model
- The overall wall construction changed from R-20 to R-24
- The current model includes vacancy sensors (represented as a 13% LPD savings) whereas the previous model represented them as occupancy sensors (represented as 10% LPD savings).
- Trees have been modeled on the South and East side of the building to account as exterior shades
- High performing Solarban 70XL glazing removed from North skylight (existing skylight to remain).

Detailed assumptions for the analysis, including occupancy and internal loads, envelope construction, typical use schedules, and HVAC parameters, are presented at the end of this report and should be reviewed and confirmed by the design team and client.

Introduction

Atelier Ten conducted a Detailed Design & Implementation (DD&I) phase energy analysis for Building 661 of the Energy Efficient Buildings Hub, which is a 2-story building located at the Navy Yard in Philadelphia, Pennsylvania. The building will be undergoing a complete renovation, with a program consisting of approximately 37,925 ft^2 of conditioned area including offices, research spaces, conference rooms, symposium and i-Con lab.

The energy model is based on the August 03, 2012 drawing set and conversations with the design team. The model includes building geometry, construction types, material properties, internal loads, and HVAC systems. Modeling assumptions for operating schedules, set points, lighting power densities, equipment power densities, and HVAC systems and efficiencies were based upon information gathered from the design team. The results will change as the design progresses and as new information is provided in the future.

Atelier Ten created the energy models using eQUEST v3.64 (DOE-2.2 simulation engine). These energy models allow for the comparison of relative energy use throughout the year and assist in identifying specific energy demands for heating, cooling, pumps, fans, lighting, equipment, and hot water. The first energy model, referred to as “Baseline Design”, meets the minimum requirements stipulated in Appendix G of ASHRAE 90.1-2007. The second energy model, referred to as “Proposed Design”, represents the current design. Atelier Ten created these two models to compare the energy performance of the current design against the ASHRAE baseline building.

This report begins with a summary of results and then provides discussion about the major energy drivers in the building. Next, the report discusses the results of the analysis with respect to annual energy and utility cost savings for all the measures listed above. This report concludes with recommendations, list of next steps for the design team, and an appendix with the energy model assumptions.

Energy models are representations of the designed building and its future operations. Energy modeling is a design optimization tool which estimates the energy performance of a building. The results from the energy model are accurate in terms of comparative evaluations of energy optimization measures assuming that all the other assumptions remain consistent. However, because energy model results rely on many assumptions about building occupancy patterns, they should not be construed as an absolute prediction of future building energy use.

Summary of Results

The energy model estimates various energy uses throughout the year and identifies specific uses for heating, cooling, pumps, fans, lighting, equipment and hot water. Figure 1 summarizes these end uses in terms of annual site energy (million Btus). Based on the modeling assumptions, the Proposed Design shows an annual energy consumption savings of around 42.9% over an ASHRAE 90.1-2007 Appendix G baseline building.

Heating energy in the Proposed Design is significantly lower compared to the Baseline Design, primarily due to reduced heating loads from the additional wall and roof insulation, heat recovery chiller, energy recovery wheel, high efficiency condensing boilers, and demand controlled ventilation. There is a significant reduction in space cooling energy due to improved glazing, improved envelope insulations, high efficiency chiller and displacement ventilation. The chilled beam systems further reduces the cooling energy needs because of the lower conditioned outside air requirement and higher chilled water temperature supplied to the beams. The fan energy has also gone down because of the lower fan power consumption at the RTU's, FCU's, VRV units and the chilled beam systems. Finally, daylight dimming contributes to lighting savings, as well as cooling savings due to reduced internal heat gains.

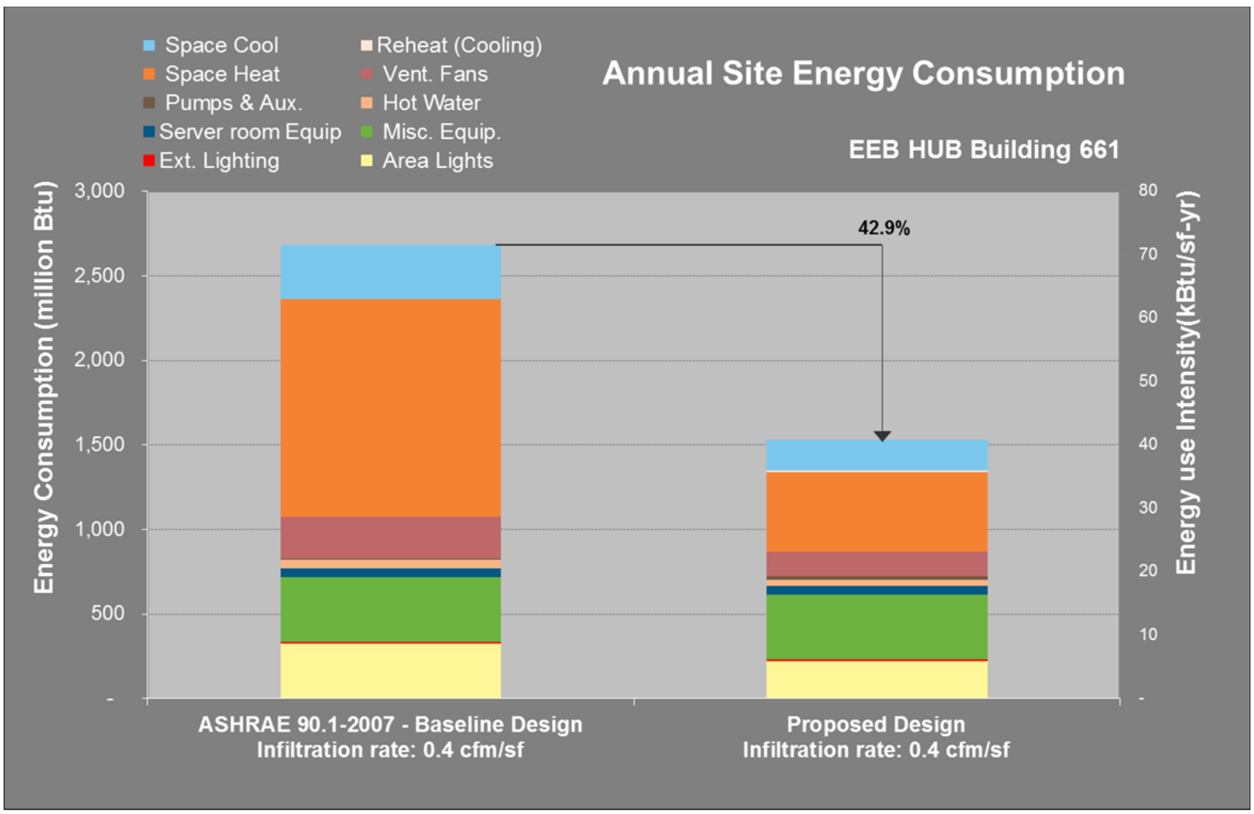


Figure 1: Annual Energy Consumption Comparison

The Proposed Design shows an annual energy cost savings of around 32.6% compared to an ASHRAE 90.1-2007 Appendix G baseline building. Large electricity savings result primarily from cooling, fan energy and lighting energy reduction and natural gas savings are achieved through the heating energy reduction. Note that the cost savings percentage (32.6%) is lower than the energy savings percentage (42.9%), this occurs because most of the energy savings comes from reduction in natural gas use, and natural gas has a much lower cost per unit energy than electricity.

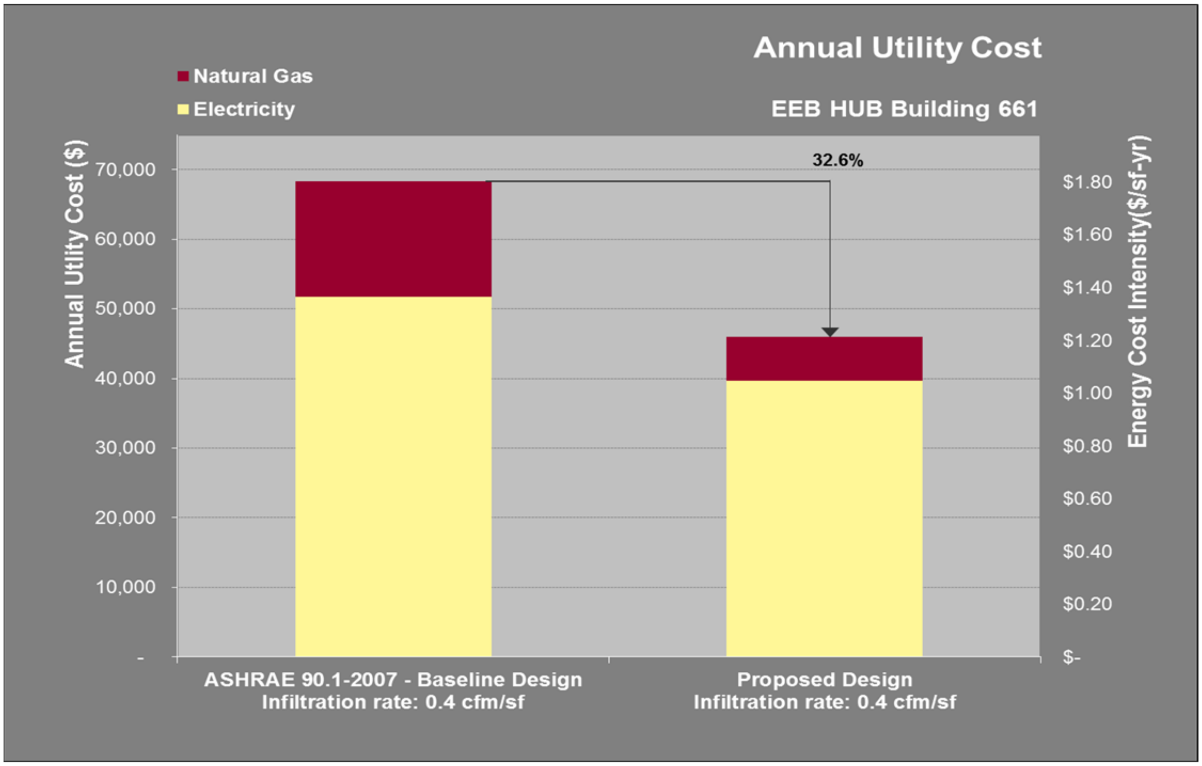


Figure 2: Annual Energy Cost Comparison

The annual CO_2 emission for the proposed building is 33% less as compared to the baseline, the percentage of CO_2 emission is very similar to the energy cost savings because of the lower CO_2 emission rate of natural gas compared to electricity.

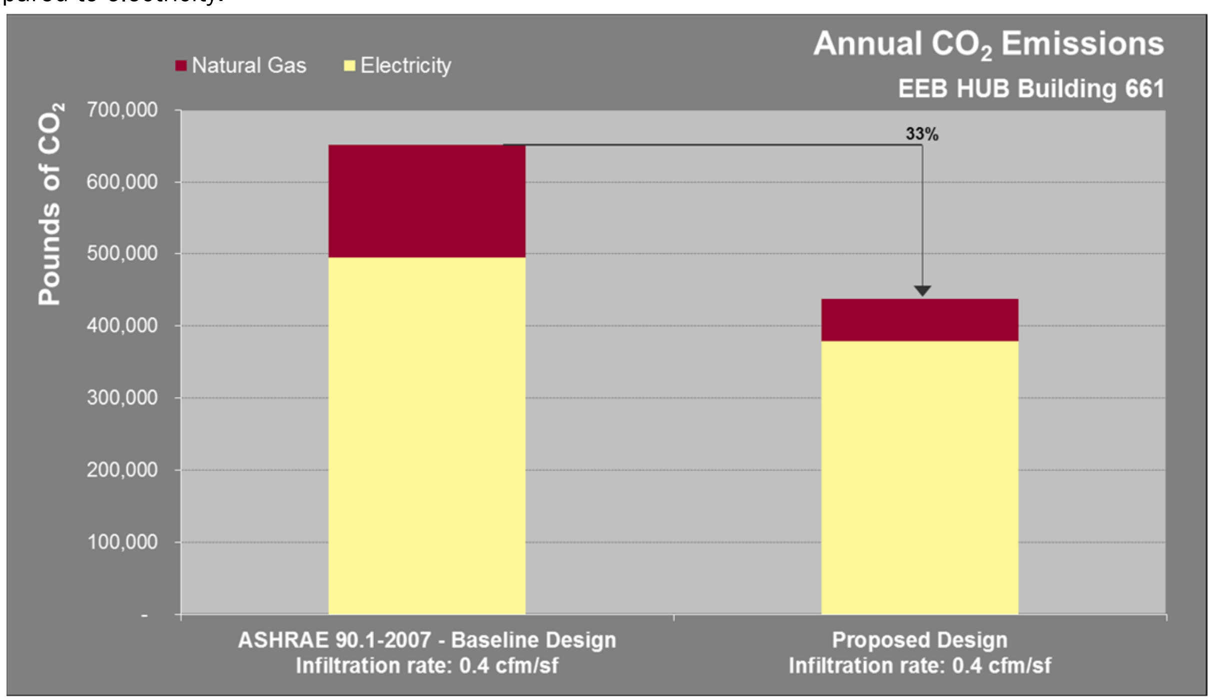


Figure 3: Annual CO_2 emission Comparison

In the preliminary DD&I energy model, the Proposed Design and Baseline Design were both assumed to have the same infiltration rate of 0.4 ACH (a very air tight building, close to 0.1 cfm/sf). Based on the blower door test conducted on September 13, 2012, the building envelope air leakage rate (0.6 cfm/sf at 75PA pressure differential) was applied to the Baseline Design in the graphs below. The following graphs (Figures 4 and 5) estimate the annual energy and energy cost savings with varying envelope infiltration rates applied to the Proposed Design. As seen from the results the project can achieve more than 50% annual energy savings and 38% energy cost savings by having a very air tight envelope.

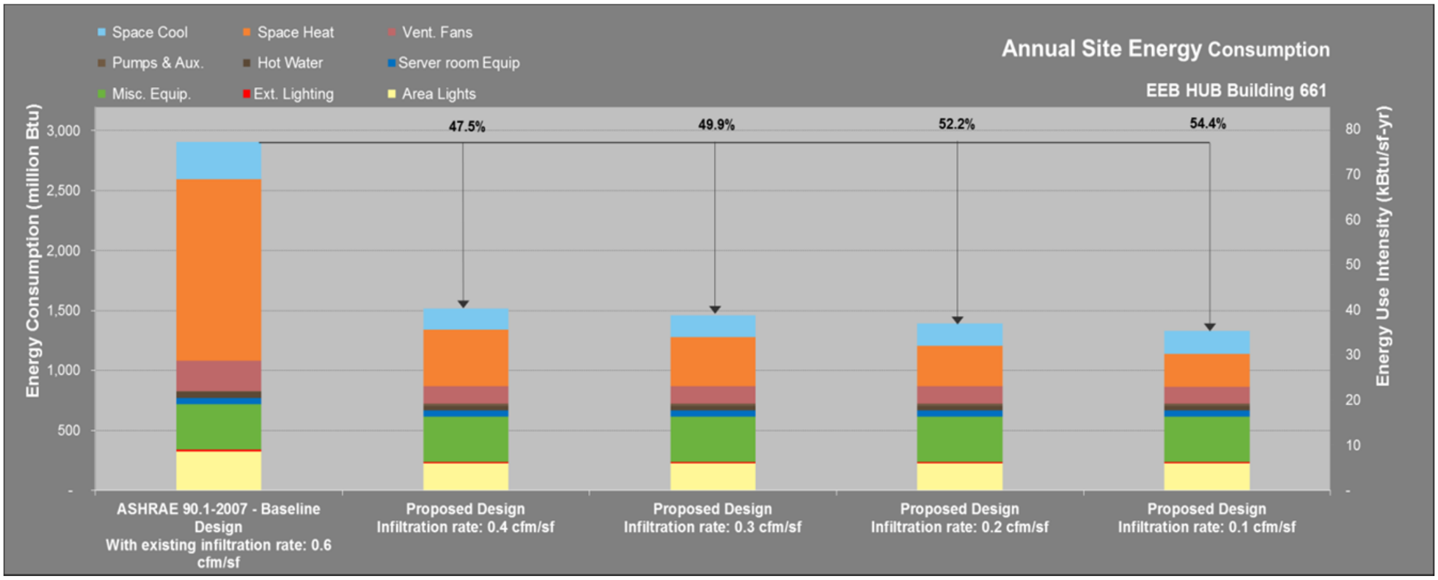


Figure 4: Annual Energy Consumption Comparison (with varying infiltration rates)

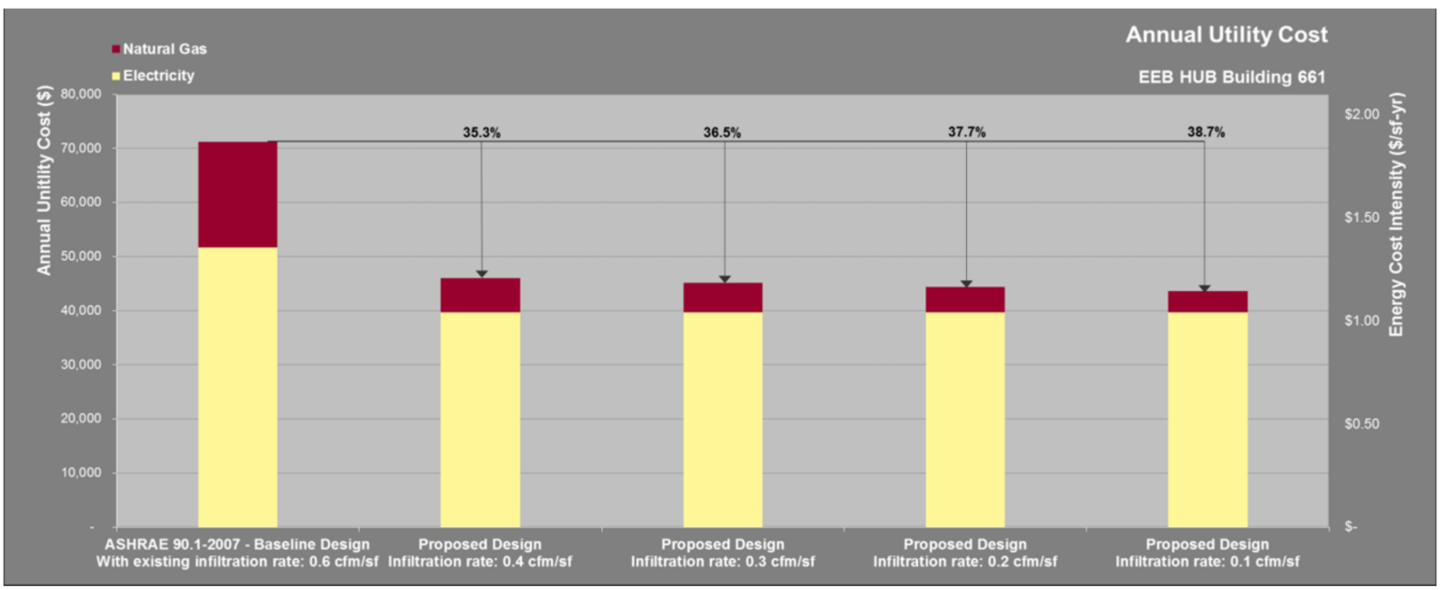


Figure 5: Annual Energy Cost Comparison (with varying infiltration rates)

It should also be noted that Appendix G does not have a standard energy modeling method for claiming credit for infiltration right now. An exception calculation could be submitted to claim credit for a reduced air leakage rate, but would be subject to approval from USGBC. In order to claim any credit a post construction infiltration test would need to be conducted so that energy savings could be based on the difference between the measured pre and post air leakage rates.

Energy Star Target Finder

Another goal of the DD&I energy analysis is to assess whether the design is 50% better than a comparable building in the Energy Star database (75th percentile of existing buildings using Energy Star rating system). This goal was established in the sustainability workshop with the design team and EEB HUB during the Conceptualization Phase in January 2012.

Based on this model, building 661 Proposed Design rating is in the range of 94 - 97, which is far better than the target rating of 75. The exact value is sensitive to the building occupancy and operating hours, so several scenarios were evaluated to establish a likely range.

Atelier Ten also tested the Energy Star rating for the Baseline Case energy model which ranged from 74 to 81. This indicates to the team that perhaps the rating target 75 is not ambitious enough and the teams should discuss increasing the target to a higher benchmark score.

For reference, a median existing building of this type has a rating of 50. The EPA provides reference targets that are based on the energy consumption of existing buildings, as collected by the U.S. Department of Energy, Energy Information Administration's 2003 Commercial Buildings Energy Consumption Survey (CBECS).

Upon completion, if the project meets or exceeds the target rating of 75, the client can apply for "Designed to Earn the ENERGY STAR Certification" and then upon verification of actual performance earn the "Energy Star Label."

Please note that the rating is based upon the current project data and could change based on future changes in the project data. The inputs for the Energy Star Target Finder include zip code, program, area, operating hours, workers, number of personal computers, air conditioning, heating, and estimated design energy. For more info on inputs and outputs for the Energy Star Target Finder, please see the Appendix.

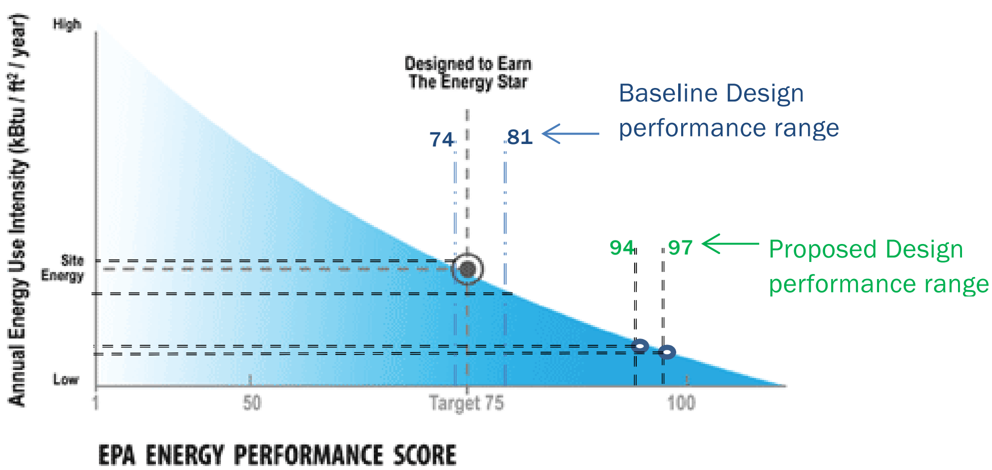


Figure 7: Energy Star Target Finder Graph

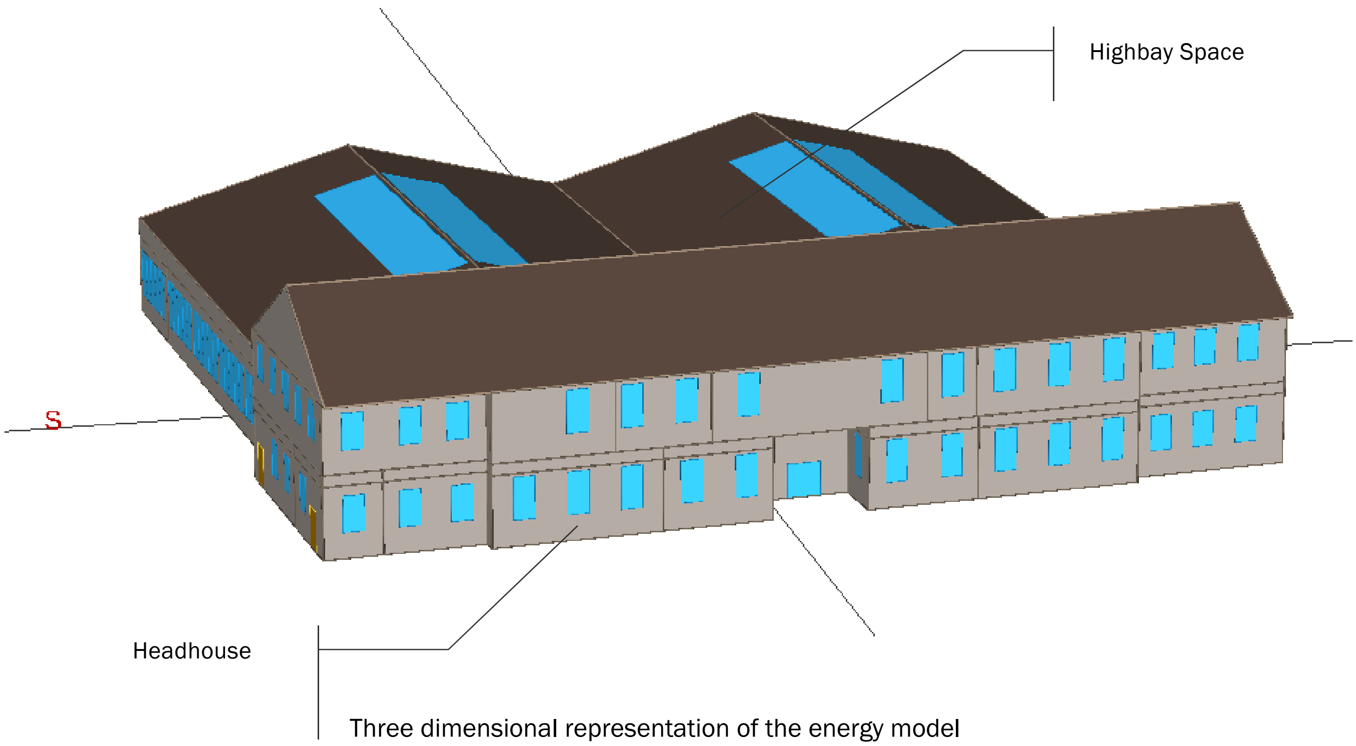
Recommendations and Next Steps

The project is currently on track to meet its energy goals. An additional blower door test after the renovation is recommended to quantify the improvement in air tightness and take credit for it in the energy model. During the construction phase, Atelier Ten will complete a final energy model to document LEED EA credit 1.

Appendix

Appendix A: General modeling parameters

Analysis Tool: eQUEST (DOE 2.2 Engine) v3.64
Weather File: DOE 2.2 TMY2 weather file for Philadelphia, PA
ASHRAE Climate Zone: 4A
Building Area (as simulated with DOE 2.2): appx. 37,925 gross ft²
Number of Floors: 2 above grade, mezzanine
Existing Renovation / New Construction: 100% / 0%
Principal Heating Source: Hot Water from Condensing Boilers
Principal Cooling Source: Chilled Water from Air-cooled Chiller



Three dimensional representation of the energy model

Appendix B: Building envelope construction

Building Element	Proposed Design	Baseline Design
Envelope		
Exterior Wall Construction	Typical Wall Construction: Existing wall (8” CMU) 1” Airspace1” Continuous insulation R-15 Spay insulation Air gap with metal studs Gypsum board Assembly U-Factor: 0.0423 Btu/hr-ft^2-°F (R-24)	Existing Wall Construction: 8" Brick 1” Airspace 4" CMU Assembly U-Factor: 0.255 Btu/hr-ft^2-°F (R-4)
Roof Construction	Typical Roof: Metal roof assembly Continuous spray insulation Assembly U-Factor: 0.032 Btu/hr-ft^2-°F (R-30)	Existing Roof: Headhouse: R-19 batt insulation (many holes) Assembly U-Factor 0.10 Btu/hr-ft^2-ºF (R-10) Highbay: R-20 insulation above deck Assembly U-Factor 0.048 Btu/hr-ft^2-ºF (R-21)
Slab-on-Grade Construction	Concrete Slab-on-Grade Assembly F-Factor: 0.73 Btu/hr-ft-°F 6” concrete	ASHRAE 90.1-2007 Appendix G Slab-on-Grade Table 5.5-5 Unheated Slab Assembly F-Factor: 0.73 Btu/hr-ft-ºF
Window-to-Wall Ratio	17.25%	13%
Glazing Description (windows and skylights)	Typical Glazing: Double glazed units (VE 1-2M with argon) with thermally broken aluminum frame for East, West and North windows, and South head house windows. Solarban 70XL with thermally broken aluminum frame for South high bay windows and skylights.	Existing Glazing: Double glazed units with aluminum frame (head house) Glass block at North high bay space Single glazed unit at south skylight
Glazing U-Factor (windows and skylights)	VE 1-2M: Assembly: 0.32 Btu/hr-ft^2-°F Solarban 70XL: Assembly: 0.27 Btu/hr-ft^2-°F South Skylight: Assembly: 0.36 Btu/ hr-ft^2-°F North Skylight: [illegible] as Baseline	Existing Glazing: Assembly: 0.67 Btu/hr-ft^2-°F Existing Skylight: Assembly: 0.57 Btu/ hr-ft^2-°F
Glazing SHGC (windows and skylights)	VE 1-2 M: 0.37 (COG) Solarban 70XL: 0.3 (COG)	Existing Glazing: 0.71
Glazing VLT (windows and skylights)	VE 1-2 M: 70 % Solarban 70XL: 64 %	Existing Glazing: 80%
Infiltration	0.3 cfm$_{75}$/ft^2 * Converted to eQuest input of 0.0712 cfm/ft^2 *	0.6 cfm$_{75}$/ft^2* based on the blower door test data Converted to eQuest input of 0.1424 cfm/ft^2

*Air leakage rate of the building envelope at 75 pa pressure differential converted to eQuest input of peak infiltration as a function of floor area

Appendix C: Building occupancy, lighting power density and equipment load

Building Element	Proposed Design	Baseline Design
Lighting		
Interior Lighting Power Density	Offices: 2.48 W/sqft Labs: 1.32 W/sqft Conference Rooms: 1.3 W/sf Symposium/Icon Lab: 1.05 W/sf Mechanical: 0.8 W/sf Storage: 0.5 W/sf Corridors: 0.44 W/sf Restroom: 1.37 W/sf Lobby: 0.65 W/sf Lounge: 1.56 W/sf	ASHRAE 90.1-2007 Compliant (Table 9.6.1) Offices: 1.1 W/sqft Labs: 1.1 W/sqft Conference Rooms: 1.3 W/sf Symposium/Icon Lab: 1.4 W/sf Mechanical: 1.5 W/sf Storage: 0.5 W/sf Corridors: 0.5 W/sf Restroom: 0.9 W/sf Lobby: 1.3 W/sf Lounge: 1.1 W/sf
Daylighting Controls	Continuous daylight dimming controls in perimeter spaces and highbay central area Illuminance target: Office, Labs: 50 fc Meeting rooms: 40 fc Telepresence: 100 fc	None.
Vacancy / Occupancy Sensors	Vacancy Sensors present in most areas, including offices, lab rooms, conference rooms, Lobbies and Mechanical rooms Occupancy sensors present in rest rooms, , storage areas and mechanical rooms 13% LPD credit for spaces with vacancy sensors (based on results from Washington State University OCCSENS study) 10% LPD credit for spaces with occ. sensors)	In areas required by Section 9.4.1.2 (classrooms, break rooms, conference rooms).
Exterior Lighting Power Density	Same as Baseline Design	ASHRAE 90.1-2007 Compliant
Equipment		
Receptacle Equipment	labs: 1.5 W/sf offices: 1.5 W/sf Open area in the high bay: 0.25 W/sf meeting rooms: 2.0 W/sf Icon lab: 1.5 W/sf Symposium: 2 W/sf Server room: 10W/sf	Same as Proposed Design
Occupancy		
Occupant Density	Lab rooms: 100 sf/person Offices: 120 sf/person Conference areas: 30 sf/person i-Con lab: 60 people Symposium: 114 people Server room: 500 sf/person	Same as Proposed Design
Building Schedule	See attached occupancy schedules	Same as Proposed Design

Appendix D: Building occupancy, lighting and equipment schedules

The following schedules for occupancy, lighting, and equipment estimate the diversified occupancy and electric usage pattern for different types of spaces for every hour of the year. Schedules are described in the form of percentage of maximum occupancy density (or total occupancy), or percentage of peak lighting and equipment loads in every hour. Please note the lighting schedules listed are the typical uncontrolled lighting schedules and do not reflect the application of lighting controls including occupancy sensors and daylight dimming.

Building 661 is not closed on holidays, so there are no holiday schedules listed.

Weekend occupants will only use Area 1 (the high bay space); Areas 2 and 3 (the head house) will be unoccupied on weekends.

Area 1 Schedule

Hour		**Occupancy**		**Lighting**		**Misc. Equipment**	
From	To	**Weekday**	**Weekend**	**Weekday**	**Weekend**	**Weekday**	**Weekend**
12:00 AM	1:00 AM	0%	0%	2%	2%	6%	6%
1:00 AM	2:00 AM	0%	0%	2%	2%	6%	6%
2:00 AM	3:00 AM	0%	0%	2%	2%	6%	6%
3:00 AM	4:00 AM	0%	0%	2%	2%	6%	6%
4:00 AM	5:00 AM	0%	0%	2%	2%	6%	6%
5:00 AM	6:00 AM	0%	0%	2%	2%	6%	6%
6:00 AM	7:00 AM	5%	0%	10%	2%	25%	6%
7:00 AM	8:00 AM	25%	0%	27%	2%	50%	6%
8:00 AM	9:00 AM	75%	0%	75%	2%	80%	6%
9:00 AM	10:00 AM	90%	0%	90%	2%	90%	6%
10:00 AM	11:00 AM	85%	5%	90%	10%	90%	6%
11:00 AM	12:00 PM	54%	5%	80%	10%	90%	6%
12:00 PM	1:00 PM	54%	5%	80%	10%	90%	6%
1:00 PM	2:00 PM	75%	5%	90%	10%	90%	6%
2:00 PM	3:00 PM	88%	5%	90%	10%	90%	6%
3:00 PM	4:00 PM	90%	5%	90%	10%	90%	6%
4:00 PM	5:00 PM	89%	5%	89%	10%	90%	6%
5:00 PM	6:00 PM	82%	0%	86%	2%	90%	6%
6:00 PM	7:00 PM	66%	0%	76%	2%	84%	6%
7:00 PM	8:00 PM	29%	0%	35%	2%	49%	6%
8:00 PM	9:00 PM	12%	0%	20%	2%	31%	6%
9:00 PM	10:00 PM	5%	0%	10%	2%	6%	6%
10:00 PM	11:00 PM	2%	0%	2%	2%	6%	6%
11:00 PM	12:00 AM	2%	0%	2%	2%	6%	6%

Areas 2 & 3 except Symposium and i-Con Lab

Hour		**Occupancy**		**Lighting**		**Misc. Equipment**	
From	**To**	**Weekday**	**Weekend**	**Weekday**	**Weekend**	**Weekday**	**Weekend**
12:00 AM	1:00 AM	0%	0%	2%	2%	6%	6%
1:00 AM	2:00 AM	0%	0%	2%	2%	6%	6%
2:00 AM	3:00 AM	0%	0%	2%	2%	6%	6%
3:00 AM	4:00 AM	0%	0%	2%	2%	6%	6%
4:00 AM	5:00 AM	0%	0%	2%	2%	6%	6%

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
5:00 AM	6:00 AM	0%	0%	2%	2%	6%	6%
6:00 AM	7:00 AM	5%	0%	10%	2%	25%	6%
7:00 AM	8:00 AM	25%	0%	27%	2%	50%	6%
8:00 AM	9:00 AM	75%	0%	75%	2%	90%	6%
9:00 AM	10:00 AM	90%	0%	90%	2%	90%	6%
10:00 AM	11:00 AM	85%	0%	90%	2%	90%	6%
11:00 AM	12:00 PM	54%	0%	80%	2%	90%	6%
12:00 PM	1:00 PM	54%	0%	80%	2%	90%	6%
1:00 PM	2:00 PM	75%	0%	90%	2%	90%	6%
2:00 PM	3:00 PM	88%	0%	90%	2%	90%	6%
3:00 PM	4:00 PM	90%	0%	90%	2%	90%	6%
4:00 PM	5:00 PM	89%	0%	89%	2%	90%	6%
5:00 PM	6:00 PM	82%	0%	86%	2%	90%	6%
6:00 PM	7:00 PM	66%	0%	76%	2%	84%	6%
7:00 PM	8:00 PM	29%	0%	35%	2%	49%	6%
8:00 PM	9:00 PM	12%	0%	20%	2%	31%	6%
9:00 PM	10:00 PM	5%	0%	10%	2%	6%	6%
10:00 PM	11:00 PM	2%	0%	2%	2%	6%	6%
11:00 PM	12:00 AM	2%	0%	2%	2%	6%	6%

Note that the Symposium is assumed to be fully occupied two times per week.

Symposium Schedule

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday TR	Weekend & MWF	Weekday TR	Weekend & MWF	Weekday TR	Weekend & MWF
12:00 AM	1:00 AM	0%	0%	2%	2%	6%	6%
1:00 AM	2:00 AM	0%	0%	2%	2%	6%	6%
2:00 AM	3:00 AM	0%	0%	2%	2%	6%	6%
3:00 AM	4:00 AM	0%	0%	2%	2%	6%	6%
4:00 AM	5:00 AM	0%	0%	2%	2%	6%	6%
5:00 AM	6:00 AM	0%	0%	2%	2%	6%	6%
6:00 AM	7:00 AM	0%	0%	2%	2%	6%	6%
7:00 AM	8:00 AM	25%	0%	25%	2%	25%	6%
8:00 AM	9:00 AM	90%	0%	90%	2%	45%	6%
9:00 AM	10:00 AM	90%	0%	90%	2%	45%	6%
10:00 AM	11:00 AM	90%	0%	90%	2%	45%	6%
11:00 AM	12:00 PM	90%	0%	80%	2%	45%	6%
12:00 PM	1:00 PM	90%	0%	80%	2%	45%	6%
1:00 PM	2:00 PM	90%	0%	90%	2%	45%	6%
2:00 PM	3:00 PM	90%	0%	90%	2%	45%	6%
3:00 PM	4:00 PM	90%	0%	90%	2%	45%	6%
4:00 PM	5:00 PM	90%	0%	90%	2%	45%	6%
5:00 PM	6:00 PM	0%	0%	2%	2%	6%	6%
6:00 PM	7:00 PM	0%	0%	2%	2%	6%	6%
7:00 PM	8:00 PM	0%	0%	2%	2%	6%	6%
8:00 PM	9:00 PM	0%	0%	2%	2%	6%	6%
9:00 PM	10:00 PM	0%	0%	2%	2%	6%	6%
10:00 PM	11:00 PM	0%	0%	2%	2%	6%	6%
11:00 PM	12:00 AM	0%	0%	2%	2%	6%	6%

The i-Con lab is assumed to be fully occupied once per day for 4 hours per day.

i-Con lab Schedule

Hour		Occupancy			Lighting			Misc. Equipment		
From	To	Weekday MWF	Weekday TR	Weekend	Weekday MWF	Weekday TR	Weekend	Weekday MWF	Weekday TR	Weekend
12:00 AM	1:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
1:00 AM	2:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
2:00 AM	3:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
3:00 AM	4:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
4:00 AM	5:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
5:00 AM	6:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
6:00 AM	7:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
7:00 AM	8:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%
8:00 AM	9:00 AM	90%	0%	0%	90%	2%	2%	45%	6%	6%
9:00 AM	10:00 AM	90%	0%	0%	90%	2%	2%	45%	6%	6%
10:00 AM	11:00 AM	90%	0%	0%	90%	2%	2%	45%	6%	6%
11:00 AM	12:00 PM	90%	0%	0%	90%	2%	2%	45%	6%	6%
12:00 PM	1:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
1:00 PM	2:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
2:00 PM	3:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
3:00 PM	4:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
4:00 PM	5:00 PM	0%	90%	0%	2%	90%	2%	6%	45%	6%
5:00 PM	6:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
6:00 PM	7:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
7:00 PM	8:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
8:00 PM	9:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
9:00 PM	10:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
10:00 PM	11:00 PM	0%	0%	0%	2%	2%	2%	6%	6%	6%
11:00 PM	12:00 AM	0%	0%	0%	2%	2%	2%	6%	6%	6%

Server room operates 24/7 and is served by its own split system. The server room has a very low occuoancy and Lighting power density.

Server Schedule

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
12:00 AM	1:00 AM	0%	0%	5%	5%	50%	50%
1:00 AM	2:00 AM	0%	0%	5%	5%	50%	50%
2:00 AM	3:00 AM	0%	0%	5%	5%	50%	50%
3:00 AM	4:00 AM	0%	0%	5%	5%	50%	50%
4:00 AM	5:00 AM	0%	0%	5%	5%	50%	50%
5:00 AM	6:00 AM	0%	0%	5%	5%	50%	50%
6:00 AM	7:00 AM	0%	0%	5%	5%	50%	50%
7:00 AM	8:00 AM	60%	0%	70%	5%	70%	50%
8:00 AM	9:00 AM	80%	0%	90%	5%	70%	50%
9:00 AM	10:00 AM	90%	0%	90%	5%	80%	50%

10:00 AM	11:00 AM	75%	0%	90%	5%	80%	50%
11:00 AM	12:00 PM	50%	0%	90%	5%	100%	50%
12:00 PM	1:00 PM	50%	0%	90%	5%	100%	50%
1:00 PM	2:00 PM	75%	0%	90%	5%	100%	50%
2:00 PM	3:00 PM	90%	0%	90%	5%	100%	50%
3:00 PM	4:00 PM	90%	0%	90%	5%	100%	50%
4:00 PM	5:00 PM	90%	0%	90%	5%	100%	50%
5:00 PM	6:00 PM	80%	0%	90%	5%	80%	50%
6:00 PM	7:00 PM	60%	0%	90%	5%	80%	50%
7:00 PM	8:00 PM	20%	0%	90%	5%	80%	50%
8:00 PM	9:00 PM	0%	0%	5%	5%	70%	50%
9:00 PM	10:00 PM	0%	0%	5%	5%	70%	50%
10:00 PM	11:00 PM	0%	0%	5%	5%	60%	50%
11:00 PM	12:00 AM	0%	0%	5%	5%	50%	50%

Appendix E: HVAC system parameters

The building is served by three different system types. Spaces in the high bay area (Area 1) are served by 2-pipe passive and active chilled beams and a dedicated outdoor air (DOAS) unit with desiccant dehumidification and an enthalpy wheel. Mezzanine spaces in the high bay have under floor air distribution with fan coil units. Chilled water is provided by an air-cooled heat recovery chiller and hot water by a condensing boiler. Most spaces in the headhouse (Area 2) are served by a packaged rooftop units with DX cooling and gas furnace heating, with underfloor air distribution on the second floor. Offices on the first floor of the headhouse (Area 3) are served by variable refrigerant volume fan coil units with natural ventilation. Areas 1 and 2 have perimeter radiator hot water heating (fin tube convectors).

Design Conditions

The chart below show interior space design conditions:

Space	Heating temp °F	Cooling temp °F	High RH %	Low RH %
General Areas	Occupied: 70 Unoccupied: 55	Occupied: 76 Unoccupied: 85	Area 1: occupied & unoccupied: 50% Areas 2 and 3: no maximum RH	0%

Description of the Proposed Building and Baseline Building System Parameters

The chart below describes the HVAC modeling assumptions for the Proposed and Baseline Building models.

Building Element	Proposed Design	Baseline Design
Mechanical Systems		
Primary HVAC System Type	Area 1 (high bay spaces & mezzanine): Dedicated outdoor air unit with desiccant dehumidification to meet ventilation requirements and latent loads. Area 2 (headhouse): Packaged VAV rooftop units with DX cooling and gas furnace heating. Area 3 (headhouse offices): Variable refrigerant volume units with natural ventilation.	ASHRAE 90.1-2007 Appendix G System Type 5: Packaged VAV with reheat One System per Floor
Other HVAC System Type	Area 1: Active and passive chilled beams provide sensible cooling and radiator hot water heating in high bay areas. (Note the bleacher area has a fan power box instead of chilled beam in that location only). Fan coil units provide heating and sensible cooling for mezzanine area. Area 2 (headhouse): Radiator hot water heating in perimeter zones. VAV terminal boxes for 1st Floor zones identified as Area 2 Server rooms: Packaged Variable volume	System Type 3: Packaged Rooftop Air conditioner Serving server room

	variable temperature system	
Air Distribution	Overhead mixed distribution for most spaces. Air distribution from floor diffusers for 2nd floor mezzanine only. Under floor air plenum with displacement diffusers 2nd floor headhouse, iCon lab and symposium.	Overhead Mixed
Air-Side Cooling		
Minimum Supply Temperature	Area 1 including mezzanine: 65˚F Area 2 second floor: 65˚F (coming off of cooling coil at 55 F with hot gas reheat to 65F) Area 2 first floor: 57˚F	55°F
Cooling Source	Chilled water for chilled beams and DOAS; DX cooling for packaged VAV rooftop units	Same as Proposed
Supply Air Temperature Control	Reset the fan speed based on room temperature	Reset higher by 5°F under minimum cooling load conditions
DX Efficiency	Area 2 Packaged RTUs: 12 EER Area 3 VRF system: 4 COP Server room systems: 16 SEER Elevator machine room cooling: 16 SEER	9.3 EER
Air-Side Heating		
Maximum Supply Temperature	85°F	90°F
Heat Source	Hot Water for fin tube convectors at perimeter and DOAS. Recovered heat from heat recovery chillers fed in to the hot water loop for DOAS post heating coil and VAV terminal heating coils Gas furnace for packaged VAV rooftop units	Hot Water
Zone Heating	VRV, fan coils, fin tube convectors at perimeter except single offices	VAV terminal reheat
Heating Efficiency	Gas furnace: 80% VRF system: 3.5 COP	80%
Outdoor Air		
Design Ventilation Rates	ASHRAE 62.1-2007 minimum rates: Area 1: DOAS: 4,300 cfm Area 2 system: Ventilation Total: 1,470 cfm RTU 1: 350 cfm RTU 2: 750 cfm RTU 3: 370 cfm Area 3 system: Naturally ventilated	Same as Proposed Design
Air-side Economizer Cycle	Area 1 DOAS does not have economizer Area 2 systems (RTUs) has drybulb economizer, high limit 65°F (includes maintaining space return humidity setpoints)	None (not required).

Heat Recovery	Area 1: 75% latent & sensible Area 2: 68% latent, 73% sensible	None
Demand Control Ventilation	Carbon dioxide sensors in most spaces modulates outdoor air based on occupancy	Symposium space
Fan Power and Flow		
Fan Power	DOAS: 0.001356 kW/cfm supply, 0.000703 kW/cfm return RTU 1: 0.000689 kW/cfm RTU 2: 0.000676 kW/cfm RTU 3: 0.000617 kW/cfm VRV: 0.1" w.g. Fan coil units: 0.166 bhp each Exhaust fans: Skylight fans (turn on at 81F): 0.1" w.g. AV rack in ICON lab:0.1" w.g.	ASHRAE 90.1-2007 Appendix G fan power 0.000702 kW/cfm
Minimum Flow Ratio (supply VFD fan reduction limit)	Area 1 System: Primary airflow to meet ventilation requirements. Lower limit is 30% Area 2 System: 30%	0.4 cfm/sf
Minimum flow at terminal boxes from RTU 3	30%	
Water-Side Cooling		
Chiller Type	Air-cooled chiller with heat recovery	N/A
Chiller Efficiency	0.3749 EIR for cooling only 0.2132 EIR at heat recovery mode	N/A
Chilled Water (CHW) Loop	Low temp loop: 43°F supply / 57°F return Plate & frame heat exchangers between loops Passive & active chilled beam loop: 60°F supply / 63°F return	N/A
CHW Loop Temp Reset Parameters	No chiller reset (always at 43) Chilled beam loop reset up to 60° or 65˚ F based on dewpoint	Same as Proposed Design
CHW Loop Configuration	Variable primary flow	Constant primary / variable secondary
Primary CHW Pump Speed Control	Variable speed drive	Variable speed drive
Water-Side Heating		
Boiler Type	Condensing Boiler – To DOAS heating Coil, FCU's, VAV reheat and fin tube convectors at perimeter	Natural Draft Boiler
Boiler Efficiency	96%	80%
Hot Water Loop	160°F supply / 110°F return	180°F supply / 130°F return
HW Loop Temp Reset Parameters	Reset down based on OA temperature	Reset down based on OA temperature
HW Loop Configuration	Variable primary	Variable primary
Pump description	Primary, secondary VFD pumps on boiler	

	loops	
Domestic Water Heating		
DHW Equipment Type	Natural gas	Same as Proposed Design
DHW Flow	0.4 GPM	Same as Proposed Design
DHW Efficiency	90%	80%
Temperature Controls	120°F distribution temperature	Same as Proposed Design

Appendix F: Utility Rates

Utility rates used in the energy model are listed below. Based on emails received March 16, 2012 and discussion that these rates are representative for the region.

Electricity (PECO):
$0.1108 / kWh
$4.96/kW
$16.41/month

Natural Gas (Philadelphia Gas Works):
$1.22 / therm
$18.00/month

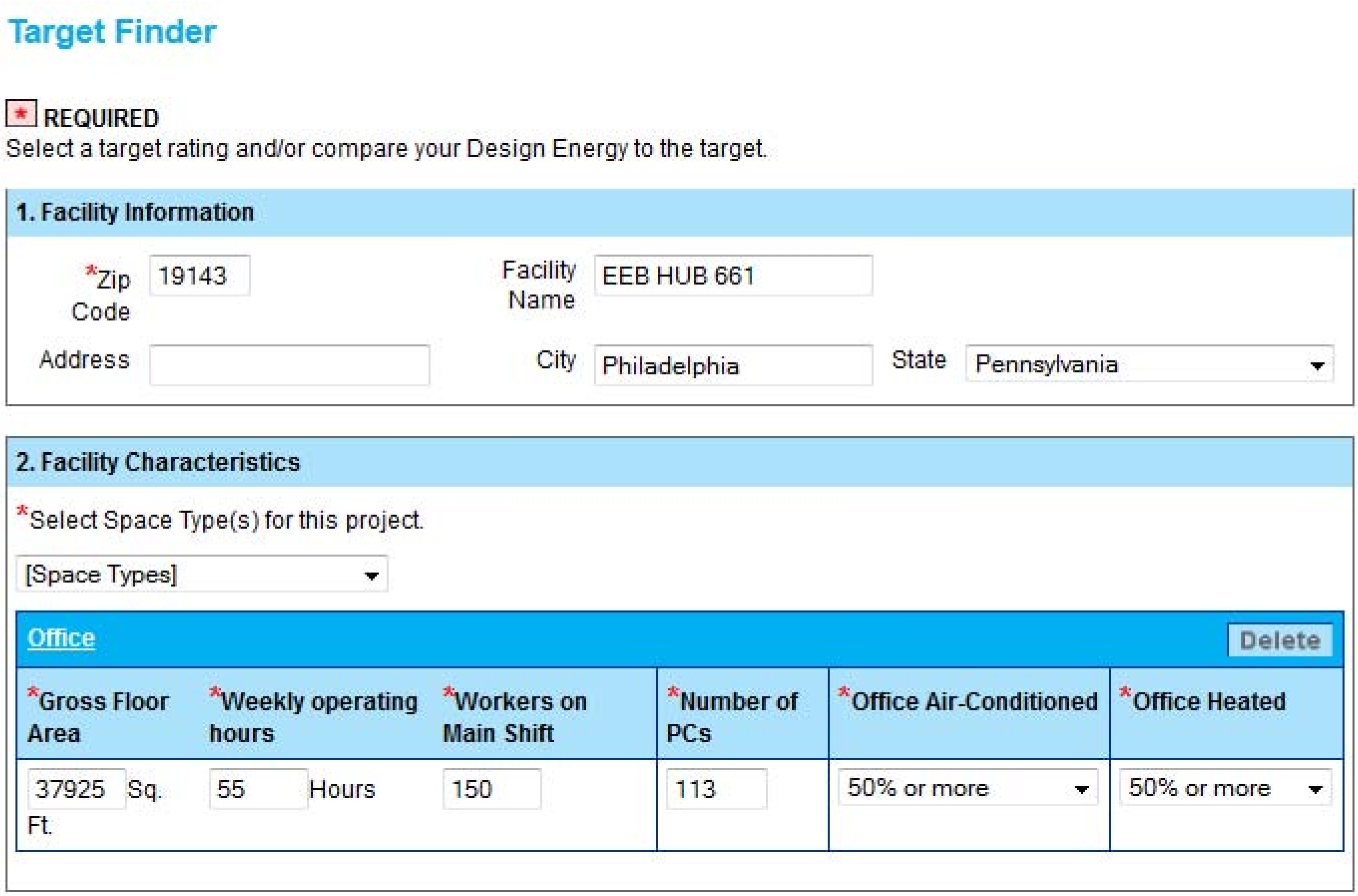
Atelier Ten analyst: JP
Report reviewed by: MT/WKM

Appendix H: Energy Star Target Finder Assumptions and Results

Table of different scenarios evaluated in Energy Star Target Finder

	Occupancy (Nos)	Operating hours (per week)	Number of PC's	EPA energy performance score
Case 1	200	40	91	96
Case 2	250	40	113	94
Case 3	250	45	113	97
Case 4	150	45	113	94
Case 5	150	40	113	94
Case 6	113	55	107	95
Case 7	150	55	113	95

Sample Input Page


Target Finder

* REQUIRED
Select a target rating and/or compare your Design Energy to the target.

1. Facility Information

*Zip Code	19143	Facility Name	EEB HUB 661		
Address		City	Philadelphia	State	Pennsylvania

2. Facility Characteristics

*Select Space Type(s) for this project.

[Space Types]

Office — Delete

*Gross Floor Area	*Weekly operating hours	*Workers on Main Shift	*Number of PCs	*Office Air-Conditioned	*Office Heated
37925 Sq. Ft.	55 Hours	150	113	50% or more	50% or more

3. The Target[1]

Target Rating | Energy Reduction Target

75 Or Select

*Choose the design target and select "**View Results**" to display associated energy use for the target.

4. Estimated Design Energy

Use results from energy analysis and enter total estimated energy for the design. Select "**View Results**" to compare Estimated Energy Use to your Target.

Energy Source	Units	Estimated Total Annual Energy Use[2]	Energy Rate ($/Unit)
Electricity - Grid Purchase	MBtu	1028	$ /MBtu
Natural Gas	MBtu	502	$ /MBtu
[Select Energy Source]			$ /

Clear Form **View Results**

[1]"Target Score" uses the EPA Energy Performance Rating of 1 -100. A project with a score of 75 or higher is eligible for Designed to Earn the ENERGY STAR certification. "Percent Energy Reduction" is the percent reduction of the Design Energy from the median energy consumption of a similar building with the median being the equivalent of a Rating of 50. The energy reduction target is acceptable for establishing Architecture 2030 and AIA 2030 Commitment goals. Note: The percent of electricity and natural gas (displayed at the top of the Results screen) are the fuel mix percentage from DOE-EIA determined by zip code and space type to calculate energy use targets.

[2]"Estimated Total Annual Energy Use" should include all energy for plug, process and other non-regulated loads, including energy generated from occupant and systems schedules and all energy fuel sources used in the design project. Note: Wind and or/solar energy that will be sold back to the grid shouldn't be included in the estimated total annual energy use.

Output page

Results

The design achieved a rating of 75 or higher:

APPLY for "Designed to Earn the ENERGY STAR"

NOTE: Values are 67% Electricity - Grid Purchase and 33% Natural Gas. The Target & Median Building energy use for this facility are calculated based on fuel mix of input estimated energy use.

View Statement of Energy Design Intent

Results for Estimated Energy Use			
Energy	**Design**	**Target**	**Median Building**
Energy Performance Rating (1-100)	95	75	50
Energy Reduction (%)	55	26	0
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	104	172	232
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	40	66	90
Total Annual Source Energy (kBtu)	3,959,114	6,508,463	8,799,923
Total Annual Site Energy (kBtu)	1,530,000	2,515,196	3,400,731
~~Total Annual Energy Cost ($)~~	~~$ 33,804~~	~~$ 55,570~~	~~$ 75,135~~
Pollution Emissions			
CO2-eq Emissions (metric tons/year)	172	283	383
CO2-eq Emissions Reduction (%)	55%	26%	0%

Utility costs were not input

Facility Information Edit

EEB HUB 661
Philadelphia, PA 19143
United States

Facility Characteristics (Edit)	
Space Type	**Gross Floor Area (Sq. Ft.)**
Office	37,925
Total Gross Floor Area	37,925

* The Median Building is equivalent to an EPA Energy Performance Rating of 50.

Estimated Design Energy (Edit)			
Energy Source	**Units**	**Estimated Total Annual Energy Use**	**Energy Rate ($/Unit)**
Electricity - Grid Purchase	MBtu	1,028	$ 26.520/MBtu
Natural Gas	MBtu	502	$ 13.030/MBtu

Source: Data adapted from DOE-EIA. See EPA Technical Description.