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## **WATERFRONT TECHNOLOGY CENTER STUDY: A NEW JERSEY ECONOMIC DEVELOPMENT AUTHORITY BUILDING**



Image Source: Ballinger

# Waterfront Technology Center Study: A New Jersey Economic Development Authority Building

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Image Source: Ballinger

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## EXECUTIVE SUMMARY

This case study is prepared by the Rutgers Center for Green Building (RCGB) and was commissioned by the New Jersey Chapter of the U.S. Green Building Council (USGBC-NJ). It is a product of the Green Building Benefits Consortium (GBBC) - a partnership between the Rutgers Center for Green Building and the New Jersey Chapter of the U.S. Green Building Council. The consortium is made up of a broad range of stakeholders in the building industry, including building owners, developers, facility managers, contractors, manufacturers, architects, engineers, green building experts, consultants, investment funds, government agencies and professional associations.<sup>1</sup> The partnership creates the opportunity for industry stakeholders to guide research on topics of green post occupancy evaluation (POE), such as increased energy savings and enhanced occupant satisfaction and performance, which have the potential to maximize benefits to companies and industries. In addition, a key objective of the partnership is to disseminate efficacious green building practices through a “lessons learned” framework, while also identifying the challenges of green building.

The case study building is the New Jersey Economic Development Authority’s (NJEDA) Waterfront Technology Center (Tech Center) in Camden, NJ. The NJEDA is committed to “leading by example” in matters of sustainable development and thus is a particularly appropriate case study subject. The building participated in the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) pilot program for Core & Shell and was the first public project in the state to receive a LEED Gold certification. Tenant spaces also achieved LEED-CI Gold certification. This study analyzes physical performance measures in such areas as energy and water consumption, and construction and operation costs, and survey work in the areas of occupant comfort and satisfaction.

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<sup>1</sup> RGBBC owner members include/have included BASF; Back to Nature, LLC; Department of Treasury, State of New Jersey; Division of Property Management and Construction, State of New Jersey; Gensler; Liberty Property Trust; MaGrann Associates; New Jersey Chapter of the National Association of Industrial and Office Properties (NAIOP); New Jersey Future; New Jersey Home Mortgage Finance Agency (NJHMFA); PNC Real Estate Finance; Skanska; Sustainable Growth Technologies/Willow School; Turner Construction-NJ; Wachovia Bank, N.A.

## Building Operating Performance

### *Energy Usage*

**Comparative Performance:** This building outperforms conventional buildings but falls short of its intended level of performance. The results of the energy analysis suggest that the Tech Center consumes 25% more natural gas and about the same amount of electricity as would be expected based on the LEED design case modeled results (i.e., the LEED submittal), which we have adjusted for discrepancies in heating and cooling degree days and the existence of an electric pre heater. As compared to an adjusted budget case (which represents a conventional equivalent to the Tech Center), the actual natural gas intensity of the building is approximately 20% lower, and the actual electricity intensity is 8% lower than the adjusted budget case. It is important to note that electricity cost comprises 85% of annual energy costs for the whole building; thus, relatively better electric performance has more economic value.

**Unexpected Patterns:** The utility data reveal some unexpected patterns, such as peak gas usage in March and a downward trend in electricity use over the course of the year. These results speak to the complexity of understanding the performance of a multi-tenanted building which is taking a long time to reach full occupancy. Once tenants are fully established, it will be worth revisiting their patterns of energy and water usage.

### *Water Usage*

The results of the water analysis demonstrate that for the most part water use in the Tech Center is at the same level of magnitude as the LEED design case. However, a more accurate determination of the number of regular occupants is needed for a more accurate comparison between the predictions for the LEED design case and actual water consumption. In addition, predictions for the LEED design case only account for domestic water use and so it might be possible that the water consumption of the LEED design case underestimates the building's water consumption. Of note is that the average daily water consumption of the building in the last year (9/15/08-6/05/09) was 31% lower than in the



previous year. Reasons for elevated water consumption in the earlier year could range from startup transients to more responsible tenant behavior, and warrant more investigation.

## **Life Cycle Performance**

### *Life Cycle Cost (LCC)*

The life cycle cost analysis performed here shows that, when compared to the budget case modeled building, the reduced energy consumption of the as-built Tech Center results in a positive Net Present Value (NPV) relative to both the design and budget cases; the positive relative NPV is maintained across all sensitivity analyses. This represents a lifetime savings and suggests that the increased capital costs for the high-performance fixtures likely will pay off, even in the relatively short term.

### *Avoided Infrastructure Analysis – Energy and Water*

A second cost analysis of interest relates to the extent to which green buildings help to avoid the cost of building new infrastructure and/or reduce operating burdens on existing infrastructure. Existing studies on green building performance show that when compared with conventional building practices, green buildings demonstrate reductions in energy use by 30%, carbon dioxide emissions by 35%, water use by 50%, and construction waste by 50% or more.<sup>2</sup> However, we simultaneously find that typical new buildings are more electricity intensive than the typical existing building, while the natural gas intensity is slightly less, and overall energy intensity is about the same.<sup>3</sup> This is mostly due to higher plug loads, lighting and cooling, which increase electricity intensity, and lower space heating, which reduces natural gas intensity.<sup>4</sup> If one instead compares the Tech Center to a conventional new building, the result is that the Tech Center is less electricity intensive and less natural gas

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<sup>2</sup> U.S. Green Building Council Research Committee. 2007. *op. cit.*, p.13.

<sup>3</sup> Energy Information Administration, U.S. Department of Energy. 2006. Commercial Buildings Energy Consumption Survey 2003, Tables c7a, c17a, and c27a, showing energy intensity by age of building in the Mid-Atlantic region. The average year of construction for a square foot of commercial building in this region is 1958. Retrieved on February 4, 2010 from

[http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed\\_tables\\_2003/detailed\\_tables\\_2003.html#enduse03](http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#enduse03).

<sup>4</sup> Energy Information Administration, U.S. Department of Energy. 2006. Commercial Buildings Energy Consumption Survey 2003, Table e2a, showing energy intensity by end use. Retrieved on February 4, 2010 from

[http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed\\_tables\\_2003/detailed\\_tables\\_2003.html#enduse03](http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#enduse03).



intensive. In other words, green building in this manner makes things less bad at the margin and delays the time period before which new infrastructure investments are needed. At the same time, green building puts less strain on existing infrastructure operations by requiring less delivery of electricity and natural gas.

Regarding water, the typical new green building uses less water than the typical new conventional building, as is the case with the Tech Center. Thus, it too helps to avoid infrastructure capacity investments for water and wastewater and reduced operating burdens, at the margin. In order for green buildings to have more significant infrastructural impacts – whether for energy or water – more must be built (or retrofitted).

Other environmental benefits that were realized through this project that may have a positive effect on larger scale infrastructural systems include the value of reused resources (approximately 8% of the total) and the value of regionally procured products (~58%). Furthermore, 87% of wood-based products used in the project were certified through the Forest Stewardship Council, which may be presumed to have beneficial land use impacts.

## **Building Occupant Satisfaction and Performance**

### *Occupant Survey Results*

Beyond enhanced building and infrastructure performance, existing studies are beginning to substantiate how green buildings may enhance occupant satisfaction, health and other determinants of human performance. A growing body of survey research seeks to quantify these benefits and also to better understand how occupant behavior may affect building performance.

According to our survey research findings, this facility is *viewed very positively*, overall, by the limited number of people who completed the survey (n=27). In particular, a very high degree of satisfaction was expressed about the overall design and appearance of the environment, building views and with the quality of indoor air. There were also some specific areas of concern, namely exterior landscaping, privacy, noise, and thermal comfort. In addition, many respondents were dissatisfied with the location or convenience of recycling containers. In spite of these gripes, respondents indicated that they rarely put in requests for work orders to make the workspace more comfortable, choosing instead to

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make a local adjustment (e.g., in clothing). Interestingly, very few subjects identified the Tech Center as in any way “green.” This is suggestive of a kind of catch-22 of green buildings. On the one hand, they can appear and function in a manner highly similar to a conventional building, requiring very little behavioral adjustment by operators and occupants. On the other hand, for optimal building performance to be realized, it may well be necessary for operators and occupants of green buildings to be at least cognizant of green building objectives and functions.

### **Accounting for Green Building Performance: Challenges and Lessons Learned**

There are many challenges inherent in designing and operating a multi-tenanted building, especially one that by its designated use – technology incubator – could be expected to have periodic vacancies and frequent changes in occupants who may have different needs and preferences regarding building operation. These challenges may manifest as technical, relating to the performance of mechanical equipment and the efficacy of selected envelope strategies; financial, reflecting a need to balance investment between the developer and the tenants; as well as be operator and occupant-based.

Our conclusion as to the role of designing the Tech Center is that the green features did what they were expected to do for electricity use, but were less successful in limiting natural gas use. Factors that may account for the mixed performance we report include a series of design choices relating to the need to maintain optimal performance under partial load conditions. For instance, the building is able to handle partial loads (which may occur due to partial occupancy as tenants enter and exit the incubator) through the installation of two boilers each of which was sized to handle 2/3 of the design load for the building. Yet, the actual natural gas usage of the building is higher than expected. Additionally, this building, which has a large outdoor air requirement because it houses potential laboratory, includes a heat recovery system to offset the increased heating and cooling loads. The actual building performance suggests that the heat recovery system is performing less well than intended in the design. We speculate that the outside air may be oversized for current use – i.e., as of this writing in 2011, half of the 5<sup>th</sup> floor intended as lab space remains vacant<sup>5</sup> –

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<sup>5</sup> Personal communication with Steven Martorana, NJEDA, 3/17/2011

even while it may play a positive role in occupant satisfaction with building indoor air quality. The heat recovery wheel, which is intended to offset the energy penalty of these fresh air demands, seems not to be off-setting as much natural gas use as anticipated. This is an area that needs further study, as an instance of a more general challenge. How do operators maintain in a predictable manner the efficiencies built with LEED Core and Shell within the tenant spaces? LEED-CI and LEED\_EB begin to address this issue but gaps remain.

Design decisions that appear to have benefited building electricity performance include lighting and HVAC features. In addition, the building orientation (long axis east to west) in combination with sunscreen systems on the south and west elevations should facilitate reduced heating and cooling loads, as should the light-colored roof (cooling).

In terms of operating practice, we observe that the NJEDA has undertaken a number of measures to benefit the performance of the Tech Center. These include the building commissioning plan that was implemented successfully in five phases – planning, design, construction, acceptance and post-acceptance. Additionally, NJEDA achieved LEED-CI certification for its tenant fit-outs. And yet, it appears that there is more work to be done in promoting the benefits of green building to tenants. For example, building management may be able to work with tenants to find more satisfactory recycling solutions. Making a further investment in the building's landscaping and perimeter and/or explaining the nature of xeriscaping might also lead to higher levels of overall satisfaction among occupants. Additionally, when training of maintenance staff is done that as a part of commissioning, the tenants are informed of the enhancements that are made and their role in maintaining these sustainable enhancements.

By way of context, green buildings have demonstrated performance levels that range from 25% below to 30% above predicted energy savings.<sup>6</sup>A 2008 study released by the New Buildings Institute (NBI) on the energy efficiency of LEED buildings found that the Energy Use Intensity (EUI) for over half of the LEED projects in the study deviated by more than 25% from design projections, with 30% higher and 25% lower than the initial modeling

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<sup>6</sup> Cathy Turner and Mark Frankel. 2008. *Energy Performance of LEED for New Construction Buildings*. Final Report. March 4, 2008. New Buildings Institute. [http://www.newbuildings.org/downloads/Energy\\_Performance\\_of\\_LEED-NC\\_Buildings-Final\\_3-4-08b.pdf](http://www.newbuildings.org/downloads/Energy_Performance_of_LEED-NC_Buildings-Final_3-4-08b.pdf) (accessed December 22, 2008)

projections.<sup>7</sup> The authors note that variations in results are likely to come from construction changes, equipment performance and difference in operational practices. This study demonstrates that all three of these factors are in play in considering the performance of the NJEDA Tech Center.

### **Proposed Next Steps**

Additional information from the designers/builders/energy modelers to help explain observed differences between design and actual building energy use would also be useful as would more information from a larger set of building occupants, particularly on such topics as daylighting, recycling, thermal comfort and any adaptive behaviors relating to these topics. Future research should also directly measure plug loads instead of treating them as a residual and it would also be valuable to understand how well the heat recovery wheel is performing by directly measuring the amount, direction, and timing of heat transferred.

Throughout this research the biggest challenges have been in coordinating the approval to interview tenant representatives and to survey building occupants, and in developing research protocols that capture sufficient data without being intrusive and time intensive for study participants. Although we have good access to historic utility data, there have been building management staff changes that affect the time series of available operator impressions and access to building data logs. Regularizing the role of post-occupancy evaluation in the building start-up process could mitigate these concerns.

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<sup>7</sup> Turner, C, Frankel, M (2008) “Energy Performance of LEED for New Construction Buildings.” New Buildings Institute.



**Fig 1: Street view at eye level.** Source: EDA website

## INTRODUCTION



**Fig 2: Tech Center Building;** Source: Ballinger



**Fig 3: Entrance lobby;** Source: Ballinger

This case study of the Waterfront Technology Center (Tech Center) at Camden was prepared by the Rutgers Center for Green Building (RCGB). It was commissioned by the New Jersey Chapter of the U.S. Green Building Council (USGBC-NJ) in order that best practices and lessons learned could be documented and shared with the building design and construction industry as well as with operators and occupants of green buildings. The case study building, which was built by the New Jersey Economic Development Authority (NJEDA) – was the first publicly owned building in NJ to be certified by the U.S. Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED) green building rating system. In particular, this building was enrolled in the U.S. Green Building Council’s LEED Core and Shell (CS) pilot program and received the LEED-CS Gold rating.

## BACKGROUND

The New Jersey Economic Development Authority (NJEDA), a quasi-public agency, is focused on the development of facilities, particularly in urban areas, that fill a gap in the market place not addressed by the private development community. NJEDA teamed with the architectural firm Ballinger to plan and design a multi-building development called the Waterfront Technology Park in Camden's Innovation (redevelopment) Zone. The Innovation Zone was established to spur collaboration among the state's public research institutions, medical research facilities and technology businesses to encourage the more rapid transfer of discoveries from the laboratory to the marketplace. Ballinger completed the 600,000 SF master plan, and the first of its six buildings — The Waterfront Tech Center --- a 5-story, 98,225 SF multi-tenant building, for emerging technology start-up companies. The building was planned to provide production, laboratory and office spaces for businesses in the biosciences, microelectronics, advanced materials, information technology and other high-tech and life sciences fields.

The Tech Center was financed through a combination of state, federal and private funds. These included a grant award from U.S. Economic Development Authority, NJEDA equity of \$4.856 million, funds from the Camden Economic Recovery Board and private debt. NJEDA has made a voluntary commitment towards achieving LEED certification on new development projects and promoting sustainable development through "Lead by Example". This building became the first publicly developed project in New Jersey to receive LEED certification. After the Core & Shell construction was completed, the tenant fit-outs in the building also went on to achieve the LEED-CI certification.



**Fig 4: *View looking outside from the Tech Center.***  
Source: Clinton Andrews



**Fig 5: *Camden's streetscape.***  
Source: Clinton Andrews



## Building Description

The architectural firm **Ballinger** provided all architectural and engineering services for the building core and shell, as well as complete fit-out and interior design services for the building's tenants. The Tech Center was designed as a speculative multi-tenant facility with associated parking. The architects designed a flexible building core and shell that would accommodate different tenant types with varying space needs (from larger build-to-suit tenants to smaller suites for multi-tenants who would share amenities) and a wide range of programmatic uses (office, wet and dry lab research, information technology, scale up and production).

The five-storied, contemporary glass and metal building complements Camden's urban environment. The building's central service core facilitates open office spaces along the perimeter, which can be customized in modular unit sizes and configurations to handle individual operating requirements and special needs of tenants. This design approach also reflects a balance between centralized building investments and investments that are made by tenants.



**Fig 6: Camden's urbanscape from the Tech Center**  
Source: [www.appliedc.com/loc-camden.php](http://www.appliedc.com/loc-camden.php)



**Fig 7: Building perspective view.** Source: Ballinger



**Fig 8: Building entrance.** Source: Ballinger



## Building Overview

- Location:  
200 Federal Street,  
Camden, NJ
- Building Type:  
Business, Office, Commercial
- New Construction:  
Brownfield Site
- Project Scope:  
New construction, 5-storied building
- Program:  
Core & Shell, tenant spaces
- Total Cost: (land purchase excluded)  
\$10 million (Core & shell)
- Area:  
98,225 SF  
Building Footprint 20,000 SF
- Date of Completion:  
Year 2006
- USGBC LEED-CS Pilot Project:  
Gold Rating (36 points)
- USGBC LEED-CI: (for tenant fit-outs) Gold Rating (2<sup>nd</sup> floor & 4<sup>th</sup> floor)

## Building Team

- *Owner/Developer* – NJEDA
- *Architect* – BALLINGER
- *Contractor* – SKANSKA, USA
- *Civil Engineer* – PERKS REUTTER
- *Environmental Advisor* – SCHOOR DEPALMA
- *Landscape Arch.* – HILLSPRING
- *Commissioning* - DOME/TEC



## Building Layout

The Tech Center is sited on 4 acres at the corner of Federal Street and Second Street, and has five main levels with floor-to-floor height of 15 feet. The first level accommodates the double-height main lobby, a large conference room, open office space, the circulation core and the service core for the entire building. The upper levels (2 – 5) were designed as flexible open spaces on planning grid modules of 10'-4" to accommodate laboratory and office spaces. The long side of the building facing Federal Street represents its prime elevation. Parking spaces are provided on the rear side of the site.

## Green Building Strategies & Technologies

The project incorporates various green building strategies and technologies in its architectural design, base building systems, and tenant fit-outs. NJEDA Chief Executive Officer Caren S. Franzini said, “We are thrilled to receive the LEED certification for the Waterfront Technology Center, which recognizes the importance we place on sustainable design and construction.” The design team at Ballinger and NJEDA’s staff architect, Mr. Stephen Martorana, played an important role in spearheading, integrating, and implementing green design strategies and features.



**Fig 9: USGBC LEED Gold plaque**

Source: Clinton Andrews

The green design strategies listed in this report (either individually or collectively as sub-groups) address the five environmental categories (as defined by LEED) namely Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources and Indoor Environmental Quality. Summaries and further descriptions of the associated green building strategies are given below. LEED scorecards for the project appear in Appendix A.

## **SITE SELECTION & PLANNING**

- Brownfield redevelopment
- Urban redevelopment zone
- Proximity to mass transit
- Provision of Preferred Parking

## **CONSTRUCTION MANAGEMENT**

- Erosion and sedimentation control
- Construction waste management plan
- Indoor air quality management plan

## **LANDSCAPING**

- Xeriscaping
- Native/ adapted plants

## **BUILDING DESIGN**

- Orientation/Passive solar design
- Building envelope system
- Daylight, views, & glare control
- Use of permanent entryway systems
- Use of deck-to-deck partitions
- Non-smoking building
- Designated outdoor smoking areas

## **BUILDING MATERIALS**

- High albedo roofing materials
- Salvaged/refurbished/reused materials
- Recycled materials
- Indigenous/regional materials
- Certified wood
- Low-emitting materials

## **BUILDING SYSTEMS**

- Energy efficient lighting
- Light pollution reduction
- Low-flow plumbing fixtures
- Efficient centralized mechanical systems
- Heat recovery system
- Low ozone depleting potential refrigerants
- Use of high performance air filters
- Building commissioning
- Building management systems
- Use of monitoring equipment

## **OTHER FEATURES**

- Recycling program
- Green cleaning



**Fig 10: Native/adapted plants used for landscaping.** Source: Clinton Andrews



**Fig 11: High performance glazing, building envelope.** Source: Clinton Andrews



**Fig 12: Energy efficiency by maximizing daylight;** Source: Clinton Andrews

## *Site Selection and Planning*

Sustainable site planning requires a holistic approach with the aim to reuse and restore existing site systems via the adoption of ecologically based strategies.

The Tech Center is located in the City of Camden's Urban Redevelopment Zone on an underutilized Brownfield site using existing infrastructure. The Walter Rand Transportation Center and the Camden-Trenton Riverline light rail are located within 0.5 miles from the site, thus making the building easily accessible by mass transit. The site is also well connected, and in close proximity to local community services, thus increasing localized density. In addition, the project utilizes no more parking spaces than prescribed by zoning for the site, provides designated parking for car/van pools and also reserved spaces for alternative fuel vehicles.

## *Construction Management*

Sustainable construction methods can significantly reduce and/or eliminate the negative impacts of construction on the environment and on building occupants. Reduced site disturbance, waste reduction and improved indoor air quality were key strategies employed for the Tech Center.

- **Erosion and Sedimentation Control Plan:**

In compliance with the New Jersey Department of Agriculture's standards, the Tech Center's Erosion and Sedimentation Control (ESC) Plan included silt fencing, stabilized construction entrance and storm water inlet protection devices. The ESC Plan thus minimized the pollution of the New Jersey waters and damage to various environmental resources.

- **Waste Management Plan:**

The Waste Management Plan prepared by Skanska Inc. emphasized waste reduction and recycling, and diverted more than 75% of construction waste from landfill. Efficient framing contributed to waste reduction and materials – in particular, untreated wood, broken concrete and masonry, scrap metals, drywall, and cardboard were recycled. All debris was gathered and carted to a commingled dumpster, and later transported to a material processing facility. At the material processing facility the waste was manually and

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mechanically culled; recycled material was marketed to secondary markets and non-recycled material was disposed of at a landfill.

- **Indoor Air Quality Management Plan:**

Skanska Construction prepared an Indoor Air Quality Management Plan that was adhered to throughout the construction process. This plan was successful in ensuring worker and occupant health and safety. All the installed ductwork was covered with plastic cover protection. None of the ductwork has internal insulation as that could trap dirt and contaminants. During construction the Air Handling Units were run continuously and the filters were changed after completion of the space, prior to tenant move-in. A temporary return filter was installed in the return duct at the unit and Filter Media (MERV 14) was installed on all return duct openings. These temporary filters were changed after completion of construction activity. During the construction phase, the building was made weather tight and was properly ventilated through the permanent HVAC system that ran continuously to provide filtered, 100% outdoor air to workers. Temporary partitions were used as required for both security and as an environmental barrier. A clean work area was maintained at all times.



**Fig 13: Floor areas kept clean and organized**  
Source: Steven Martorana, NJEDA



**Fig 14: Construction area kept free from debris**  
Source: Steven Martorana, NJEDA



**Fig 15: Duct outlets covered during construction**  
Source: Steven Martorana, NJEDA



**Fig 16: Protected ductwork**  
Source: Steven Martorana, NJEDA





**Fig 17: Materials stored in clean areas**  
Source: Steven Martorana, NJEDA



**Fig 18: Floors kept clean during construction using sweeping compound to minimize dust**  
Source: Steven Martorana, NJEDA

## *Landscaping*

The landscape design for the Waterfront Technology Center incorporates water efficient landscaping via xeriscaping and use of native/adapted plants. Thus, a permanent irrigation system has been completely avoided.

## *Building Design*



**Fig 19: Aluminum sunscreen system on south & west elevations;** Source: Richard Wener



**Fig 20: Adjustable interior sun control fabrics in office areas;** Source: Clinton Andrews

The building orientation facilitates reduced heating and cooling loads. Its long axis is from east to west. This allows the south façade to admit the lower winter sun and be shaded from the higher summer sun. The building also incorporates aluminum sunscreen systems on the south and west elevations to reduce solar heat gain and provide enhanced daylighting characteristics. Minimal window openings have been provided on the east elevation to cut

the morning and noon heat gain in summer, and reduce heat loss in winter. The building envelope is designed to be energy-efficient by use of insulated metal panels and high performance glazing for windows. The strip window system maximizes natural daylight and views for 90% of the seated spaces and is further enhanced by the double height atrium. The glass channel system used for the staircase block on the south elevation is dual glazed; it contributes to energy efficiency, and also enhances the space quality by allowing for the passage of natural light without the loss of privacy. Adjustable interior sun control fabrics are used for glare control and reduced solar heat gain.



**Fig 21: Building envelope**  
Source: Clinton Andrews



**Fig 22: Sunshades**



**Fig 23: Strip window**

The building design and operation seeks to provide its occupants with high indoor air quality. Pursuant to state law, no smoking of any kind is permitted within any area of the building and smoking areas are delineated outside of the building, at least 25 feet away from building entries. Entryway grates are situated at the main high volume entryway to capture dirt and particulates. Deck-to-deck partitions are installed at all janitor closets to ensure physical separation of chemical use areas from other spaces.

### ***Building Materials***

The Tech Center uses building materials that contribute to reduced environmental impact and improved sustainability. A light colored, high-albedo roof is used on 100% of the roof area. This roof helps reduce the heat island effect and helps keep the building cool, reducing air conditioning needs.



The project has earned LEED points under the resource reuse category. Two refurbished TRANE chillers are reused in the Tech Center. The typical replacement value of the reused resources on the project is equivalent to 8% of the value of the total materials for the project.

In addition, the majority of the furniture in the Tech Center is also re-used product that was moved from the old office location two blocks away. Many materials with recycled content (post-consumer + ½ pre-consumer) are incorporated into this project. These include:

- Stainless steel washroom accessories
- Powder coated baked enamel toilet partitions
- Gypsum wallboards
- Wood doors with recycled core
- Interior partitions
- Light gauge metal framing products
- Mineral fiber and fiberglass ceiling products
- Steel doors and frames
- Moisture resistant MDF panels
- Millwork
- Carpet
- Galvanized steel
- Hollow metal frames and doors
- Vinyl Composition Tile (VCT)
- Rubber & vinyl wall base
- R-11 3-1/2” unfaced fiber glass insulation batts
- High pressure decorative laminate
- Porcelain stone tile

Additionally, this project has obtained LEED points indicating support for the regional economy and reduction of environmental impacts due to transportation. For instance, 58% of the total value of the materials and products used in the Tech Center were regionally manufactured and 46% of the total materials by cost were regionally extracted. Products that have contributed towards earning points under the regional materials categories include: concrete, steel, exterior & interior studs, glass, aluminum windows, rebar, metal deck, hardware, hollow metal, miscellaneous metals, wallboard, paint, rubber & vinyl wall base, wall base system, rubber tiles, hollow metal frames and doors, fiber glass insulation, high pressure laminate and toilet partitions. Furthermore, 87% of wood-based materials and products, particularly plywood, were certified in accordance with the Forest Stewardship Council’s Principles and Criteria. Low-emitting materials – adhesives & sealants, interior paints & coatings, and carpet systems – were used to advance the objective of improved indoor air quality.

## *Building Systems*

- **Building HVAC System:**

The building uses highly efficient, centralized mechanical systems, including central boilers, chillers and a custom air-handling unit with humidification and a total energy recovery wheel. The two natural gas-fired boilers are located on the ground floor and provide hot water for reheat loads and miscellaneous loads. Each is sized to handle 2/3 of the design load for the building. An electric heating coil in the custom air-handling unit also provides heat. The two air-cooled, rotary-screw chillers are located on the roof and provide chilled water for the entire building. The chilled water circulation pumps incorporate variable frequency drives, but those on the hot water circulation system do not, according to the commissioning report. Air handling equipment installed as part of the core and shell phase of the building construction includes a 50,000 cfm, 100% outdoor air unit which supports 20,000 square feet of laboratory space, and provides ventilation air to offices and common spaces in the remaining 80,000 sf of the building. This custom-built, variable-air-volume, fresh-air unit is located on the roof and it incorporates the supply fan, heat recovery wheel, gas-fired humidifier, electric heater, chilled water coil, and an exhaust fan associated with the heat recovery wheel. Ventilation supply air and return/ exhaust air are ducted down through the building in a central shaft. Taps are made at each floor, with the taps at the top two floors sized for 30,000 cfm. It allows the flexibility of having laboratory space on either floor or combination of both. The bottom 3 floors have taps sized for 5,000 cfm, allowing each for normal office use.

In the winter, the heat recovery wheel recovers heat from the building exhaust air stream and delivers it to the incoming outdoor air, which reduces the amount of energy required to heat and humidify the space. A 2003 U.S. Environmental Protection Agency energy analysis found that for typical 100,000 SF laboratory buildings, energy savings through reduced natural gas consumption ranged from 36% to 75% depending on type of system and climate zone.<sup>8</sup> Similarly, in the summer the wheel removes heat from the incoming ventilation air and rejects it into the building exhaust air stream, thus significantly

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<sup>8</sup> EPA, 2003. Laboratories for the 21<sup>st</sup> Century: Best Practices, Energy Recovery for Ventilation Air in Laboratories, [http://www.epa.gov/lab21gov/pdf/bp\\_recovery\\_508.pdf](http://www.epa.gov/lab21gov/pdf/bp_recovery_508.pdf)

reducing the amount of energy required to mechanically cool the building. In addition, the HVAC systems make zero use of CFC-based refrigerants thus contributing to environmental sustainability.

Conditioning for the tenant fit-out area is accomplished by commercial grade, 4-pipe type fan-coil units for heating and cooling. Ventilation air is delivered to each fan coil unit from the main shaft. Areas not considered high-density areas, (open offices, enclosed offices, etc), have a constant amount of outdoor air provided. High-density areas such as conference rooms and break-rooms are controlled by variable air volume boxes and locally mounted carbon dioxide sensors. Flow and energy meters are installed on each tenant fit-out project. Each floor's chilled water and heating hot water mains have meters monitoring the flow rates and temperature differential across each system. Such information is converted to the amount of energy usage of each tenant. Each tenant space also has an electric meter located in the main electrical room. Toilet rooms and janitor spaces have separate, dedicated exhaust systems.



**Fig 24: Mechanical room on ground floor**  
Source: Clinton Andrews



**Fig 25: Air-cooled chillers**  
Source: Clinton Andrews



**Fig 26: Mechanical systems mounted on roof area**  
Source: Clinton Andrews



**Fig 27: Energy controls for each tenant fit-out.** Source: Clinton Andrews

High-efficiency filters are used in the air-handling units (AHUs) for improved indoor air quality. Each AHU is provided with two sets of filters – a pre-filter (MERV 7) and final filter (MERV 14) set; all the outside air travels through both filter sets. The MERV 7 pre-filter is designed to remove larger, staining-size particles. The MERV 14 filter is designed to remove respirable-size particles that adversely affect human health. A building commissioning plan, which assessed the proper functioning of the HVAC system, was implemented successfully in five phases – planning, design, construction, acceptance and post-acceptance. The commissioning process facilitated identification of problems and conflicts early on, thus preventing extra time and costly rework that would have been otherwise required for correcting problems at a later date.



**Fig 28: Filter media return plenum**  
Source: Steven Martorana, NJEDA



**Fig 29: Filter media**  
Source: Steven Martorana, NJEDA



**Fig 30: Ductwork sealed during construction**  
Source: Steven Martorana, NJEDA



**Fig 31: Ceiling space before tenant fit-out**  
Source: Steven Martorana, NJEDA

- **Controls:**

The office area mechanical system is monitored and controlled by a Building Automation System (BAS). Office areas are zoned on the basis of their load profiles. Programmable thermostats, which are tied into the complete building automation system, are provided for each office zone and these adjust temperature according to occupancy requirements.

The base building mechanical systems are monitored and controlled by a Direct Digital Controls (DDC) system. The BAS reports all data, alarms, trend log data, etc. and consists mainly of the following components:

- BAS console
- DDC controllers to control chillers, air handlers, exhaust fans, and the heating hot water system.
- Instrumentation (sensors)
- User interface – color graphics, schedules, reports, alarms, trend logs.

The BAS also continuously monitors the carbon dioxide (CO<sub>2</sub>) levels. Carbon dioxide sensors are located in each of the thermal control zones. A Variable Air Volume (VAV) box is associated with each sensor to provide the required outdoor air to high density areas. Carbon dioxide sensors continuously monitor the space condition. If the concentration of gas exceeds above the set point programmed, variable air volume box opens to its maximum flow setting to allow more outdoor air supply to space. The VAV box responds if CO<sub>2</sub> levels cross a threshold of 1000 ppm. Typical outdoor air CO<sub>2</sub> concentrations are between 300 and 500 ppm.



**Fig 32: Carbon dioxide sensor and programmable thermostat.** Source: Clinton Andrews



**Fig 33: Energy efficient T5 fluorescent lights.** Source: Clinton Andrews



- **Lighting Design:**

The lighting design implemented in the building was 24% more energy efficient than required by code requirements that prevailed at the time (calculations were made using COMcheck<sup>9</sup>). Higher energy efficiency was achieved via the use of linear and compact fluorescent lighting fixtures. Forty-six inch (46”) T5 28W/electronic ballast linear fluorescent lights were used in the open office areas and triple 4-pin 18W/32W compact fluorescent lights (CFLs) were used in the meeting/conference rooms. The use of incandescent lights was minimized and restricted only to a few fixtures in the lobby area for overall aesthetic ambience. Light switches with built-in occupancy sensors were used in order that lights could both be manually and automatically operated. This green strategy can be easily incorporated into most designs and the switches are readily available at minimal cost. Sub-meters were installed by the utility provider PSE&G at no additional cost; as noted above, these record the energy usage of individual tenants.



**Fig 34: 46” T5 linear fluorescent lights in office areas;**  
Source: Clinton Andrews



**Fig 35: Compact fluorescent lights (CFLs) in corridors;**  
Source: Clinton Andrews

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<sup>9</sup> COMcheck is a DOE software that simplifies energy code compliance by offering a flexible computer-based alternative to manual calculations.

- **Building Commissioning:**

The systems that were commissioned as part of the Core & Shell and tenant Fit-out projects included:

1. Type: Airside
  - Air Handling Unit (AHU)
  - Toilet exhaust fan
  - Air outlets
  - Toilet exhaust outlets
2. Type: Hydronic
  - Chilled water pumps (primary and standby)
  - Hot water pumps (primary and standby)
  - Chillers (2 nos.)
  - Fan Coiled Units (FCUs)

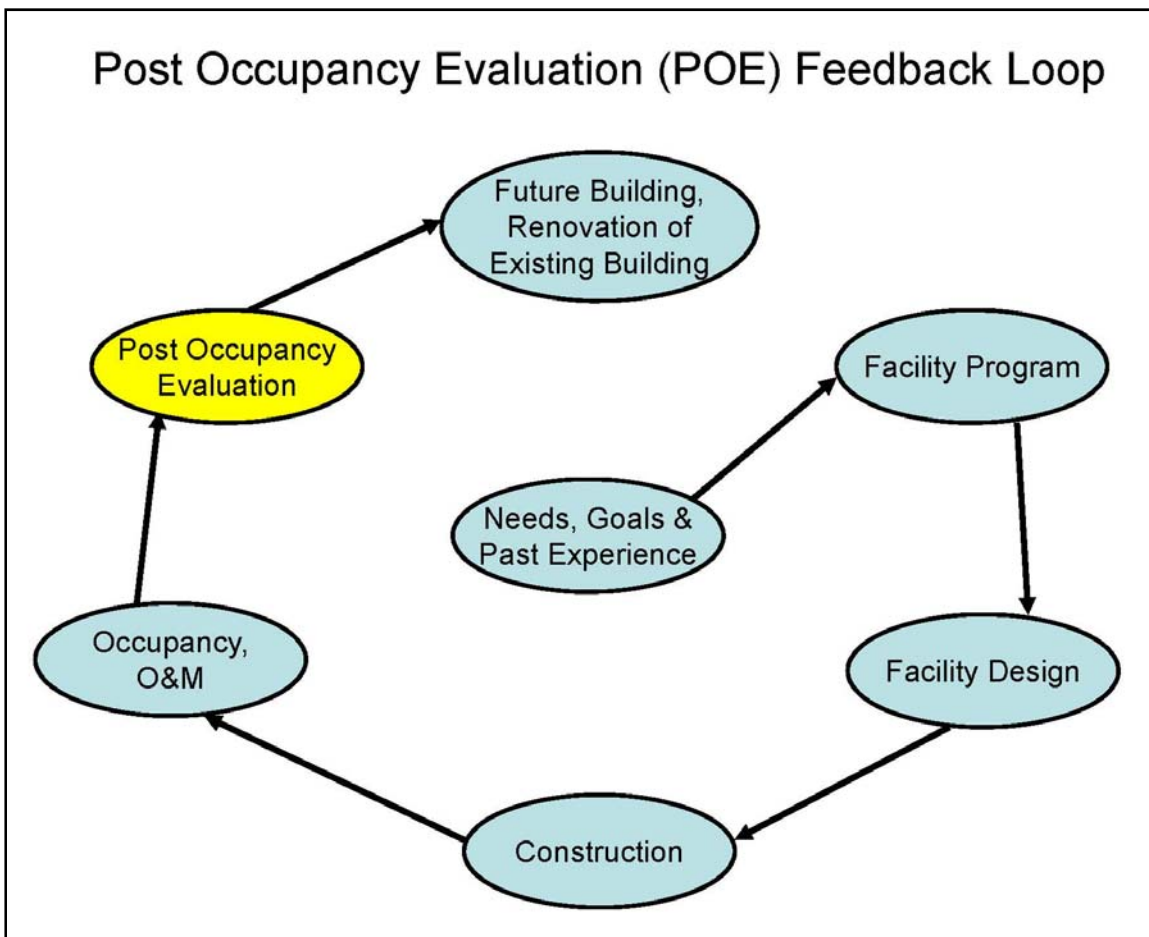
During the process, all the commissioned equipment was checked for adequacy and compliance. A final commissioning report gave recommendations, if any, for improvement to equipment and/or operations.



## RESEARCH DESIGN

### Post Occupancy Evaluation

This study evaluates the Tech Center on a variety of different parameters including environmental and economic performance, occupant satisfaction, and avoided infrastructure costs. Collectively, this research is called post occupancy evaluation (POE), although a POE need not include all of these elements. POE of green buildings tends to focus on hypotheses linked to green building benefits, and the extent to which these are realized. As with any POE, the associated analysis is part of a crucial feedback loop to inform future design choices and operating practices.



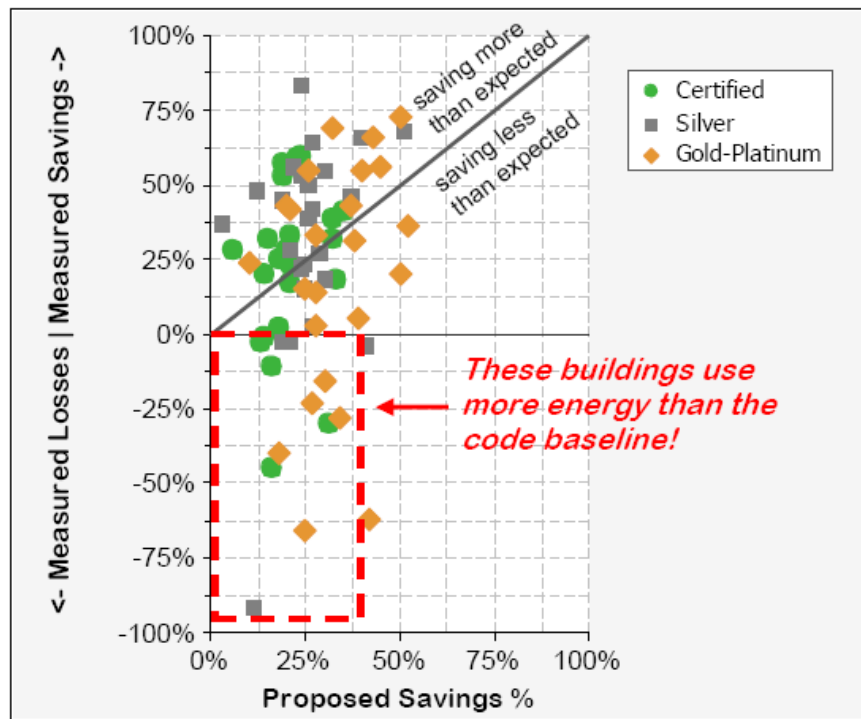
**Fig 36: Post Occupancy Evaluation (POE) Feedback Loop**

Source: Zeisel, J. (1981). *Inquiry by Design: Tools for Environment-Behavior Research*, Brooks/Cole Publishers, Monterey, CA.

## Building Performance

Indeed, green buildings have demonstrated performance levels that are both 25% below and 30% above predicted energy savings. For example, a 2008 study released by the New Buildings Institute (NBI) on the energy efficiency of LEED buildings found that the Energy Use Intensity (EUI) for over half of the LEED projects in the study deviated by more than 25% from design projections, with 30% higher and 25% lower than the initial modeling projections. The authors note that variations in results are likely to come from:

- Differences in operational practices and schedules
- Equipment performance
- Construction changes



**Fig 37: Measured Versus Proposed Energy Savings (%)**

Source: Cathy Turner and Mark Frankel. 2008. *Energy Performance of LEED for New Construction Buildings*. Final Report. March 4, 2008. New Buildings Institute.

Note: The LEED program awards energy performance points on predicted energy cost savings compared to a modeled code baseline building. The baseline is generated using the energy cost budget (ECB) approach and performance requirements in the ASHRAE 90.1 standard. Most buildings in this study used the 1999 version of this standard.

Fig 37 shows that measured energy savings for the buildings in this study average 28% compared to code baselines, close to the average 25% savings predicted by energy modeling in the LEED submittals. However, some buildings are doing much better than anticipated, as evidenced by those buildings with measured EUI below the dotted line. On the other hand, nearly an equal number are doing worse; several buildings use more energy than the predicted code baseline.

## Occupant Satisfaction & Performance

An additional component of POE focuses on how buildings may enhance employee satisfaction, health and other determinants of performance.<sup>10</sup> For example, a growing body of research shows links between enhanced human performance and such green building features as: daylighting, views to nature, improved air quality, and individual control of fresh air and temperature.

- A 1998 study by Romm and Browning reported eight case studies that show up to a 16% improvement in productivity between the employees in existing facilities and the employees in remodeled or new green facilities.<sup>11</sup>
- A 2000 study by Fisk found that **increased outdoor ventilation rates and natural ventilation significantly reduces respiratory** illness, influenza and absenteeism by 9-20%.<sup>12</sup>
- A 2001 study by Heerwagen found that workers at the new Herman Miller SQA building showed significant productivity gains and reported “overall [positive] feeling about the environment” that was 60% higher than before the move to the green facility.<sup>13</sup>

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<sup>10</sup> See the work of the Carnegie Mellon University team led by Vivian Loftness, FAIA, and Volker Harkopf, PhD, who conducted a secondary literature review of studies related to health and human benefits of green buildings and the survey by the Center for the Built Environment (CBE) at the University of California.

<sup>11</sup> Romm, J., Browning, W. (1998). “Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design”. Snowmass, CO: Rocky Mountain Institute. [http://www.rmi.org/images/other/GDS/D94-27\\_GBBL.pdf](http://www.rmi.org/images/other/GDS/D94-27_GBBL.pdf) (accessed Jan 30, 2009)

<sup>12</sup> Fisk, W.J. 2000. “Health and productivity gains from better indoor environments and their relationship with building energy efficiency.” *Annual Review of Energy and the Environment* 25(1): 537-566.

<sup>13</sup> Judith Heerwagen. 2001. “Do Green Buildings Enhance the Well Being of Workers?” *Environmental Design + Construction*. January 30, 2001.

- A 2003 study by the Heshong-Mahone Group found a 6-7% improvement in call center average handler time for workers with seated access to **views through larger windows with vegetation**, as compared to employees with no outdoor view.<sup>14</sup>
- A 2003 study the Heshong-Mahone Group demonstrated that **access to window views** improved student performance by 5-10% and that student performance dropped in classrooms where teachers were unable to control glare.<sup>15</sup>
- A 2005 study by Ries and Bilec found that productivity of manufacturing workers in the new green facility increased 25% compared to workers in the old facility.<sup>16</sup>
- A 2006 Indoor Environmental Quality study by the Center for the Built Environment at the UCLA Berkeley compared survey responses of green and non-green building occupants.<sup>17</sup> The study found that people in green buildings were more satisfied with **thermal comfort & air quality** in their workspace. Conversely, the study found that **lighting and acoustic quality** in green buildings did not show a significant improvement in comparison to non-green buildings.
- A 2008 case study review by Loftness cited 12 international case studies, which demonstrate that **improved lighting design** increases individual productivity between 0.7-23%, and 8 international case studies, which demonstrate that providing **individual temperature control** for each worker increases individual productivity by 0.2-3%.<sup>18</sup>
- A separate study by Loftness finds that high-performance ventilation systems cut respiratory illnesses by 10-90 percent.<sup>19</sup>

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<http://www.edcmag.com/CDA/Archives/fb077b7338697010VgnVCM100000f932a8c0> (accessed Jan 30, 2009)

<sup>14</sup> Heshong Mahone Group. 2003. "Windows and Offices: A Study of Office Worker Performance and the Indoor Environment." Technical Report to the California Energy Commission. October 2003.

<sup>15</sup> Heshong Mahone Group. 2003. "Daylighting n Schools: Reanalysis Report. Technical Report to the California Energy Commission. October 2003.

<sup>16</sup> Robert Ries and Melissa M. Bilec. 2006. "The Economic Benefits of Green Buildings: A Comprehensive Case Study." *The Engineering Economist* 51:3, 259 – 295.

<sup>17</sup> Abbaszadeh, S., L. Zagreus, D. Lehrer and C. Huizenga, 2006." Occupant Satisfaction with Indoor Environmental Quality in Green Buildings." *Proceedings, Healthy Buildings 2006*, Vol. III, 365-370, Lisbon, Portugal, June. [http://www.cbe.berkeley.edu/research/pdf\\_files/Abbaszadeh\\_HB2006.pdf](http://www.cbe.berkeley.edu/research/pdf_files/Abbaszadeh_HB2006.pdf)

<sup>18</sup> Loftness, V. 2008. Sustainable Design for Health and Productivity. Presentation at Brown University. November 21, 2008.

[http://envstudies.brown.edu/documents/Loftness\\_BrownCES.pdf](http://envstudies.brown.edu/documents/Loftness_BrownCES.pdf)

<sup>19</sup> Loftness et al, op cit.

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## Case Study Design

The findings about green buildings explored above suggest that the average savings and potential benefits of green buildings are well documented, but that research is needed to better understand the combination of green building strategies and technologies that lead to higher levels of building performance and corresponding environmental, economic and human benefits. The following outline illustrates the phases and specific actions endeavored by the Rutgers Center for Green Building for conducting a POE on the NJEDA Tech Center.<sup>20</sup>

### Phase 1: Baseline Research

1. **Building Owner Interview** -reviewed overall project details, responsibilities, and expectations.
2. **Design, Construction, Engineering Team Interview** - reviewed green features and performance expectations.
3. **Facility Manager Interview** - gathered detailed information about the building and FM practices; also used RCGB instruments including an online survey and Building Performance Evaluation (BPE) tool that helps to gather quantitative data in such areas as energy, water, building cost and waste.
4. **Tenant Representative Walk-through and Project Briefing** – toured some tenant facilities and explained the study. Solicited tenant participation.

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<sup>20</sup> Note that approval from the Rutgers Institutional Review Board for the Protection of Human Subjects (IRB) was been obtained for this research project. All participants signed an informed consent form as required by this protocol. Participants in the online survey were asked for their permission to participate in the survey electronically.

- As a result of this step, the study team identified an opportunity to conduct a comparative case study, within the overall study, that would seek to assess similarities and differences in occupant satisfaction. For example, two participating tenants are located on the same side of the building and share a similar line of , but have different office layouts (open-collaborative vs. private-cubicles) which we hypothesize may affect occupant satisfaction in terms of lighting, acoustics, temperature, etc.
5. **Follow-up Visit** – the purpose of the second visit was to formalize tenant participation in the study. During this interview the tenant representatives also provided specific information on usage patterns and occupant habits and agreed to have occupant-employees participate in an online survey and follow-up surveys and/or focus groups.
  6. **Background Survey** - gathered background information about the occupants and their attitude to, and experience of, the building through a brief (10 minute) online survey.
    - Rutgers worked with the tenant representative to come up with a communication plan and timeline for inviting occupants to participate in the online survey. An email invitation was sent inviting occupants to participate in the study and they were given 2 weeks to complete the survey. Incentives were used to encourage participation in the survey (e.g., drawings for a gift certificate to a local restaurant).
  7. **Building Performance Data Analysis** –performed energy and water analysis and benchmarking and a life cycle cost and infrastructure cost analysis.
  8. **Survey Analysis** – analyzed and produced the results of the occupant surveys.
  9. **Case Study Write-up** – completed this draft case study write-up.

## **Phase 2: Follow-up Research (for consideration under a different grant, from the USGBC)**

1. **Semi-/Annual Facility Manager Interview** - review utility bills, real-time monitoring results, and repeat/expand participating occupants for survey
  - In conjunction with the online survey, the team re-interviewed the facility manager (third site visit) and set up the data logging procedure to collect ongoing data in one hour increments on: Indoor temperature, temperature set points, outdoor air temperature, relative humidity (outdoor and at air handling units), carbon dioxide levels, peak and non-peak hours of the HVAC equipment. Unfortunately, RCGB has been unable to attain this data as it seems the facility manager either cannot or will not provide it.
2. **Occupant Focus Group(s)**—occupant focus groups could be used to more finely discern results of the occupant survey(s)
3. **Additional Occupant Surveys (optional)** – collect additional feedback on occupant satisfaction and behavior.



## KEY FINDINGS

This section of the report summarizes key findings from detailed inquiries into building energy usage, water usage, life-cycle costs, life cycle impacts in terms of infrastructure impacts, and occupant perceptions. Each write-up includes an explanation of purpose, introductory material, methodology, results, discussion, conclusions, and recommendations for future research.

### Building Operating Performance

#### *Energy Use*

##### **Introduction**

The Tech Center includes several energy-efficient design features that mitigate an otherwise energy-intensive set of building functional requirements. The key, energy-efficient features include a tight building envelope, an exhaust air heat recovery system, a zoned HVAC system that allows localized control and scheduling of temperature and airflows, and efficient lighting equipment. Working against these efficient technologies are the legal requirement that the laboratory spaces receive 100% fresh air, the green-building objective of achieving very high indoor air quality in both office and laboratory spaces throughout the building, and the aesthetic objective of having large amounts of window area to provide occupants with daylighting and access to views of the Philadelphia skyline.

As is typical in speculative commercial buildings, the core and shell have been constructed first, and the tenant fit-out of interior spaces has followed as tenants sign leases. The core and shell systems, therefore, have a great deal of flexibility designed into them, which sometimes limits their achievable energy efficiency. Yet, this flexibility has value because the tenant's needs, and even their fit-out requirements and connections to central systems, may diverge from the original design program. This five-story, 98,225 sq. ft building has been occupied in stages. The third floor has been occupied since May 2006, the fourth floor since August 2006, the second floor since December 2006, the first floor since September 2007, and the fifth floor remains unoccupied.

## Methodology

This analysis of energy performance compares measured performance, based on utility bills, with intended performance that is based on modeling performed as part of the LEED submittal. A comparison of this building's performance with the measured average performance of similar commercial buildings provides a further point of calibration.

Twenty months of utility bills for the common (core and shell) areas of the Tech Center were provided by NJEDA, establishing a good basis for measuring the actual energy use by the core & shell. For some tenants, only electricity cost data were available, and we converted these to electricity usage (kWh) data by dividing by monthly average electricity prices taken from the NJEDA billing records. At the beginning of 2011, the 5<sup>th</sup> floor became 50% occupied, but still no tenant data is available for this floor.<sup>21</sup>

The average performance of similar commercial buildings is based on the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS) 2003, which surveyed a sample of 5,215 U.S. commercial buildings about their design characteristics and measured energy consumption.<sup>22</sup> The CBECS data set is used in two ways in this analysis. First, the average electricity and natural gas energy intensities (energy use/square foot-year) of office and healthcare buildings located in the Mid-Atlantic region are used to synthesize a comparable building to the Tech Center.<sup>23</sup> The Tech Center is designed to include 80% office space and 20% laboratory space, so those proportions are used to create weighted-average energy intensities from the CBECS data. We assume that healthcare as a principal activity is a reasonable proxy for laboratory, which is not included as a CBECS category. The second way we use CBECS data is to adjust the modeled energy intensity estimates for missing end uses (plug loads). CBECS end-use estimates are based on the national sample, not the regional sample, by principal activity that is located in the

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<sup>21</sup> Personal communication with Steven Martorana, NJEDA, 3/17/2011

<sup>22</sup> Energy Information Administration, U.S. Department of Energy, Commercial Buildings Energy Consumption Survey (CBECS) 2003. Retrieved on January 4, 2010 from <http://www.eia.doe.gov/emeu/cbecs/contents.html>.

<sup>23</sup> CBECS 2003; Electricity from Table C17, p. 361; Natural gas from Table C27, p. 433; retrieved on January 4, 2010 from [http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed\\_tables\\_2003/detailed\\_tables\\_2003.html](http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html).

building.<sup>24</sup> This is a potential source of bias. An additional concern about using CBECS for comparative purposes is that it contains a sample of existing buildings that may have different amenities and economic value than the newly-built Tech Center.

The modeled performance of the Tech Center under two design scenarios is part of the LEED documentation required by the U.S. Green Building Council. The designers used the Trane TRACE program to model the Design scenario (similar to what was actually built) and a Budget scenario that is meant to represent a conventional building without green features.<sup>25</sup> For the current analysis, we adjusted the modeled energy intensities to include plug loads that were excluded from the earlier analysis, and also adjusted the lighting loads to distinguish between lights on the common area electric bill and the tenants' electric bills.

Following the annual energy-intensity comparisons, we look at monthly data to understand better how the building is performing. We provide weather data (monthly average temperatures, heating degree days, and cooling degree days) to help explain the pattern of observed energy use.<sup>26</sup>

## Results and Discussion

The following pages show figures that summarize the monthly climatic conditions and energy use at the Tech Center. Fig 38 shows the seasonal temperature pattern experienced in Camden, and also shows that there are only minor differences between the years 2007 and 2008. Heating Degree Days (HDD), shown in Fig 39, indicate which months make up Camden's heating season. February and April were unusually cold in 2007. Fig 40 shows Cooling Degree Days (CDD), which define Camden's cooling season. The year 2007 also included unusually hot months, making it a year of extremes. The July 2007 to June 2008 time period is the window for which the best energy consumption data are available,

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<sup>24</sup> CBECS 2003, Electricity end uses from Table E6, Natural gas end uses from Table E8, retrieved on January 4, 2010 from [http://www.eia.doe.gov/emeu/cbeecs/cbeecs2003/detailed\\_tables\\_2003/detailed\\_tables\\_2003.html](http://www.eia.doe.gov/emeu/cbeecs/cbeecs2003/detailed_tables_2003/detailed_tables_2003.html).

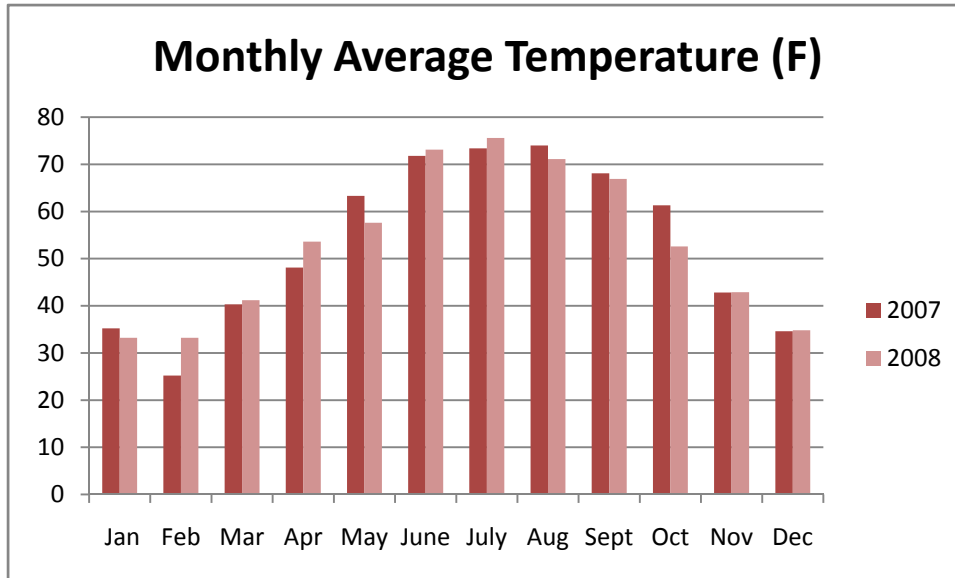
<sup>25</sup> Ballinger, Inc. Trane Trace 700 output reports submitted as documentation for LEED C&S EA credit 1.1-1.10, December 7, 2005, Philadelphia, PA. Available from NJEDA.

<sup>26</sup> Temperature data are from National Oceanic and Atmospheric Administration. Pennsylvania, Southeastern Piedmont Division, Retrieved on January 2, 2010 from <http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#>. Degree day data are from [www.degree-days.net](http://www.degree-days.net) (using temperature data from [www.wunderground.com](http://www.wunderground.com)) for Port Richmond (JcWeather), Philadelphia, PA, US (75.11W,39.98N).

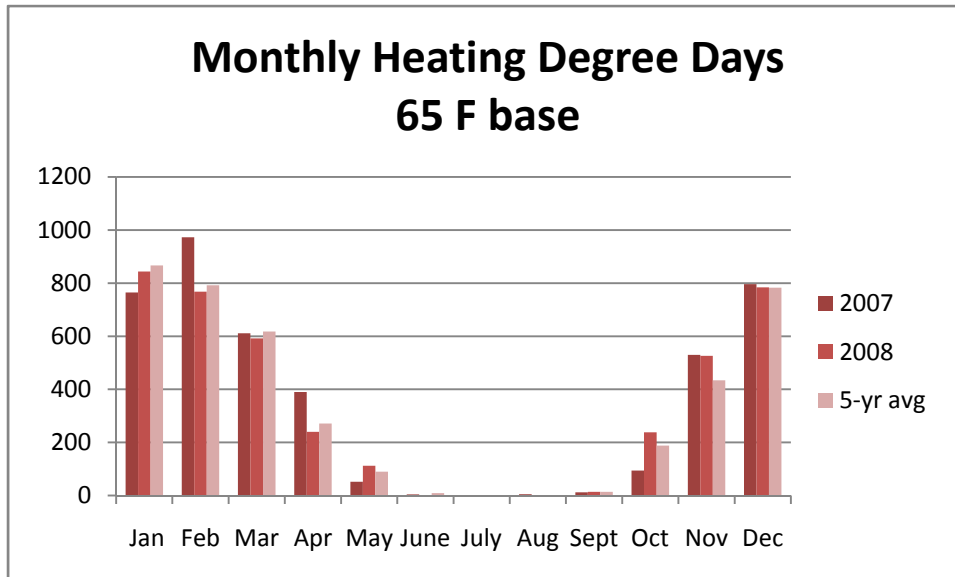
and during that time there were 3995 HDD and 2058 CDD, 2% below and 7% above average, respectively.

Natural gas consumption at the Tech Center closely follows the monthly pattern of heating degree days, as shown in Fig 41. Electricity consumption, by contrast, does not exhibit as much seasonality, as can be seen in Fig 42. Even after excluding most plug loads and lighting by plotting only the common area electricity use in Fig 43, it does not closely track cooling degree days. Instead, if a pattern can be discerned at all, there appear to be both summer and winter peaks. A plot of peak electricity demand for the common areas in Fig 44 also fails to show much seasonality. This is likely due to tenant activities in common areas. The anomalously high peak demand reading in December 2007 was verified on the electric bill, but it may be due to an accounting error by the utility company, or to tenant activities in common areas.

The total cost of energy at the Tech Center is relatively stable from month to month, although the gas/electric mix changes, as shown in Fig 45. Natural gas increases its share of the energy bill during the winter than the summer months, but overall, electricity dominates in every month.



**Fig 38: Monthly Average Outdoor Temperatures for Camden**



**Fig 39: Monthly Heating Degree Days for Camden**

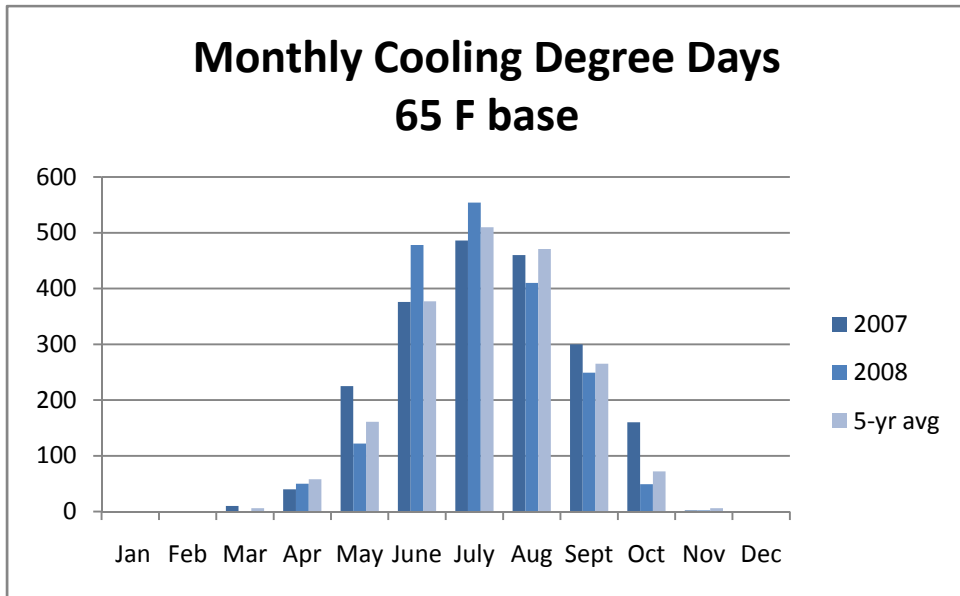


Fig 40: Monthly Cooling Degree Days for Camden

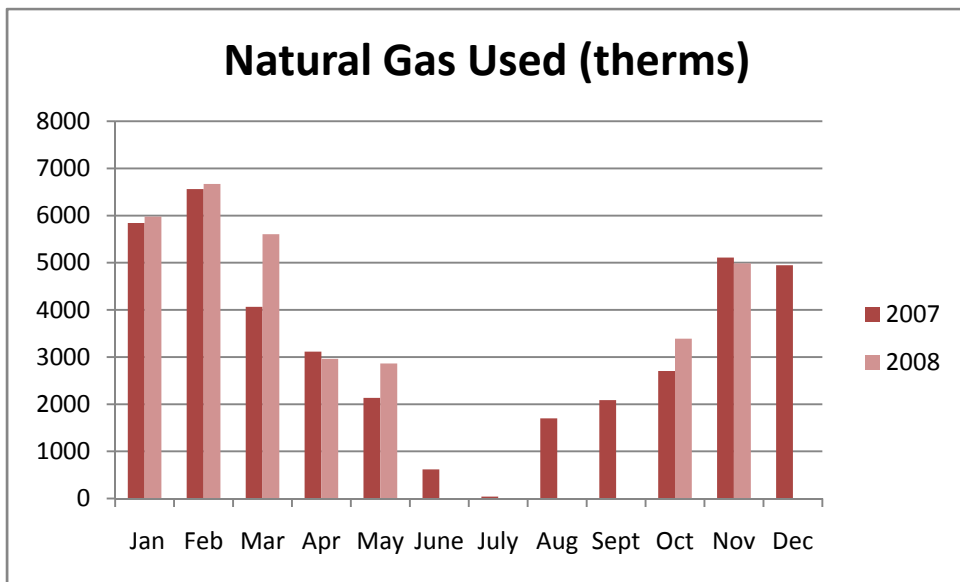
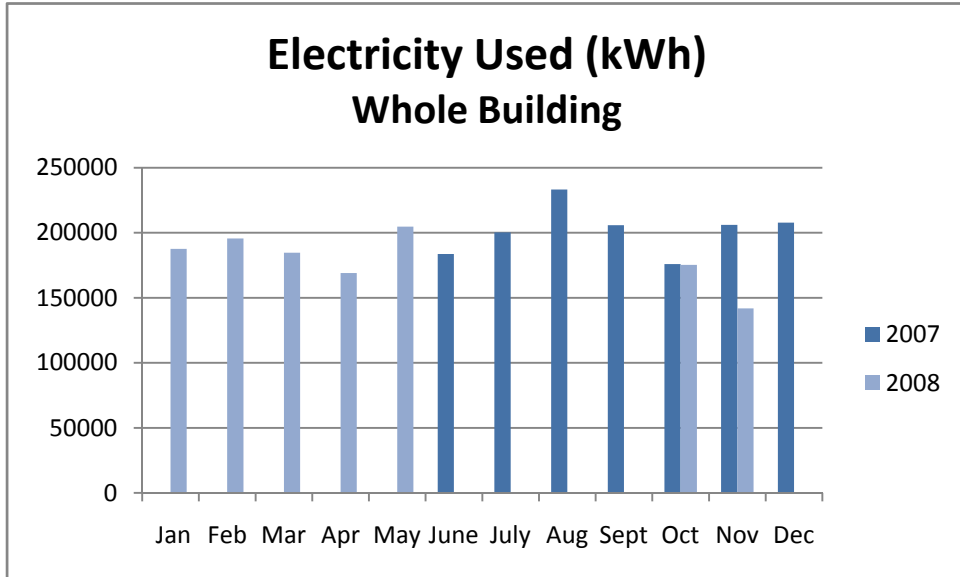
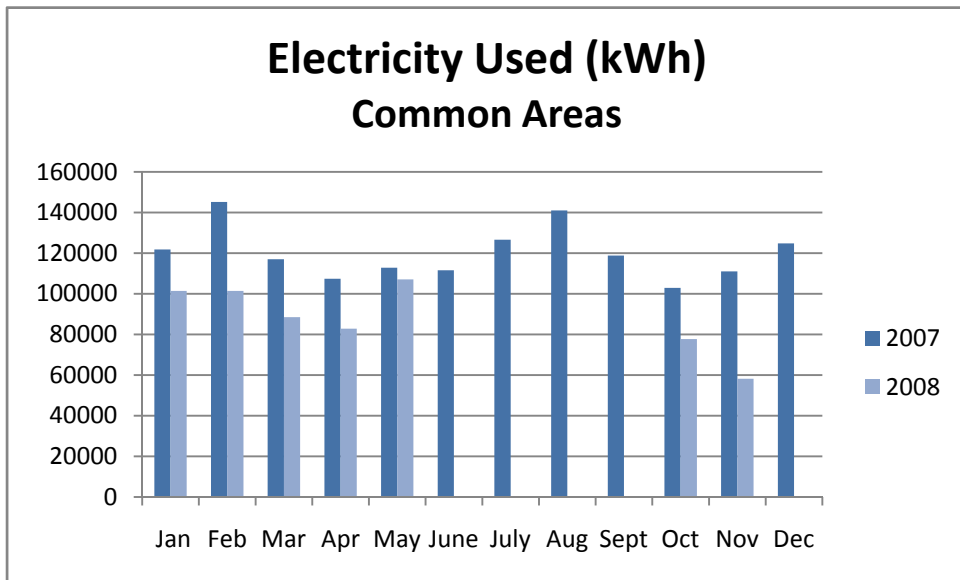


Fig 41: Monthly Natural Gas Use





**Fig 42: Monthly Electricity Use (whole building)**



**Fig 43: Monthly Electricity Use (common areas only)**

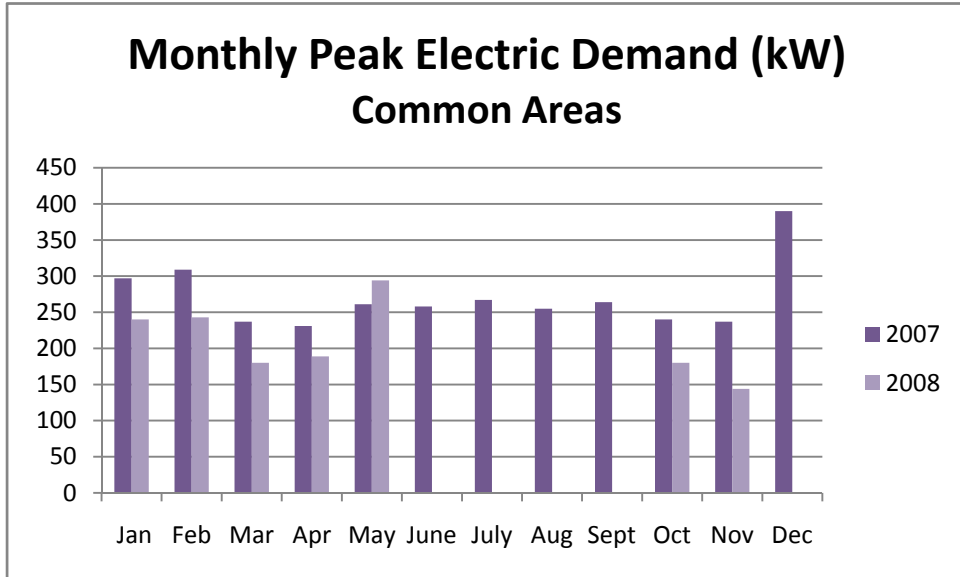


Fig 44: Monthly Peak Electricity Demand (common areas only)

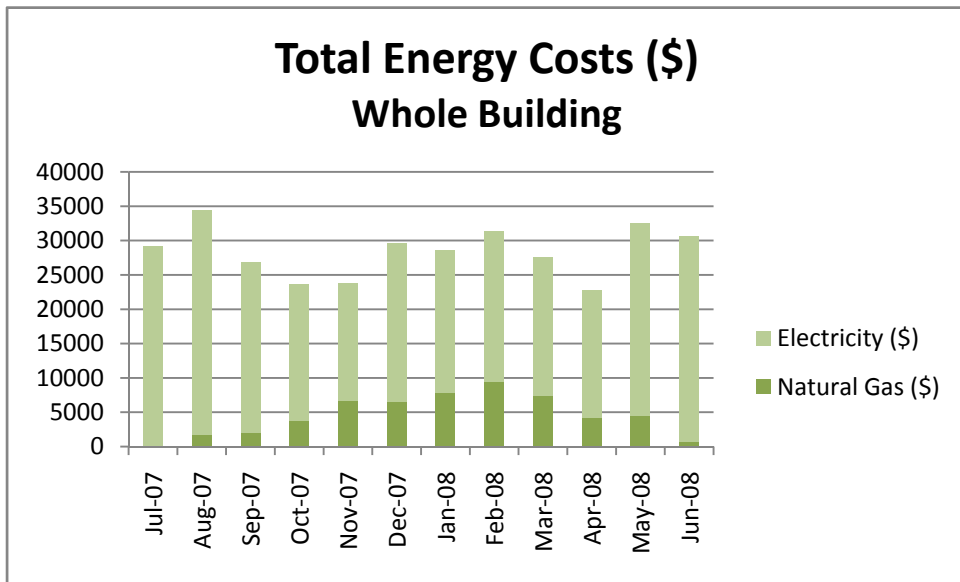


Fig 45: Monthly Energy Costs (whole building)

Annual energy intensity comparisons show that the Tech Center is using less natural gas and more electricity than expected, on a preliminary, unadjusted basis. Fig 47 shows natural gas intensities for the whole building, comparing a typical existing building (based on CBECS), the modeled scenario as designed, a modeled scenario showing the budget case

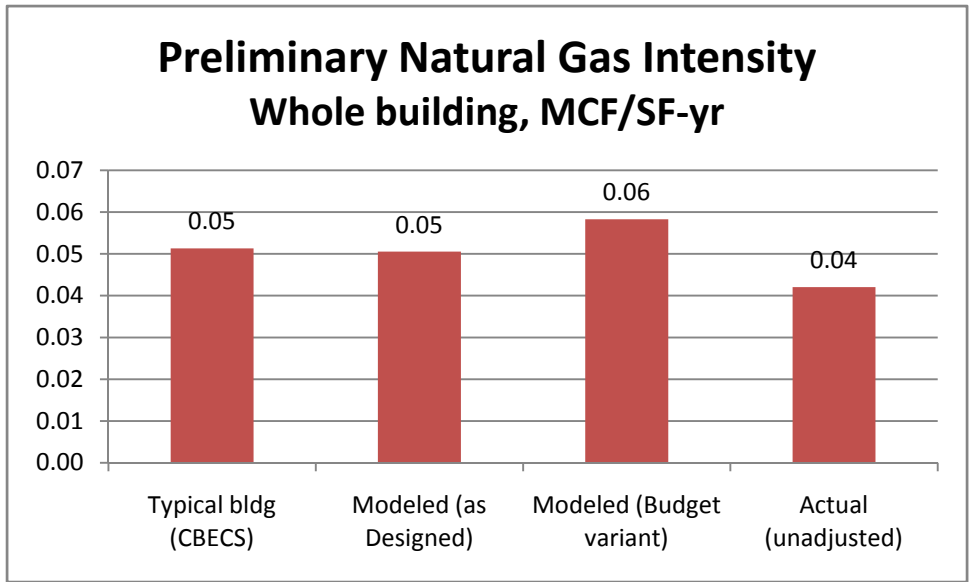
representing a conventional building without green features, and the actual natural gas consumption for the building as built, based on utility bills. The figure shows that the actual performance for natural gas use is 17% lower than predicted by the modeling, and also lower than a modeled conventional building and typical existing buildings in the region.

Fig 14 compares electricity intensities for the whole building. Here, the actual electricity intensity is 29% *higher* than predicted by the modeling. Actual electricity use also appears to be higher than typical existing buildings, and about the same as the modeled conventional (“budget”) building design.

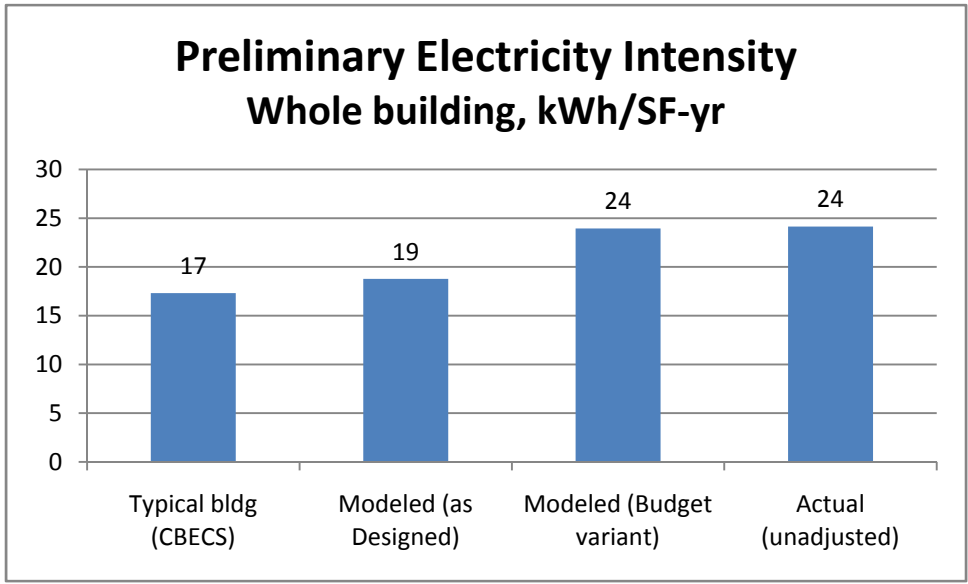
There are many factors that might contribute to these apparent differences between design intent and actual performance. We explore several of them here to understand better how the building is really performing and to provide a basis for adjusting the preliminary comparisons. Factors considered include climatic variation, design changes, occupant behavior, and startup transients, as shown in Fig. 46.

Explanatory Factor	Description	Direction of influence
Climatic variation	Actual heating and cooling needs may differ from those assumed during design (modeled location vs. actual location, current year vs. historical average degree days)	Decreases natural gas use, increases electricity use
Design changes	Actual building differs from the original design (electric pre-heat added to actual building)	Decreases natural gas use, increases electricity use
Occupant behavior	Occupants use building differently than originally anticipated (higher plug loads, different occupancy schedules)	Increases electricity use
Startup transients	Complex building systems need tuning, operators need training, building takes time to become fully occupied	Operational problems increase energy use, high vacancy rate decreases it

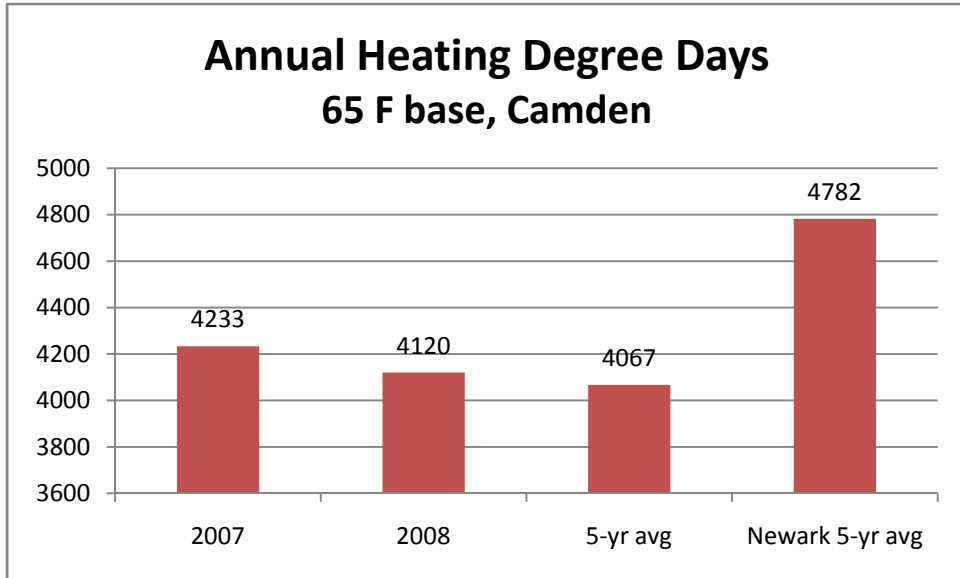
**Fig. 46: *Factors Explaining Discrepancies between Actual and Intended Energy Performance***



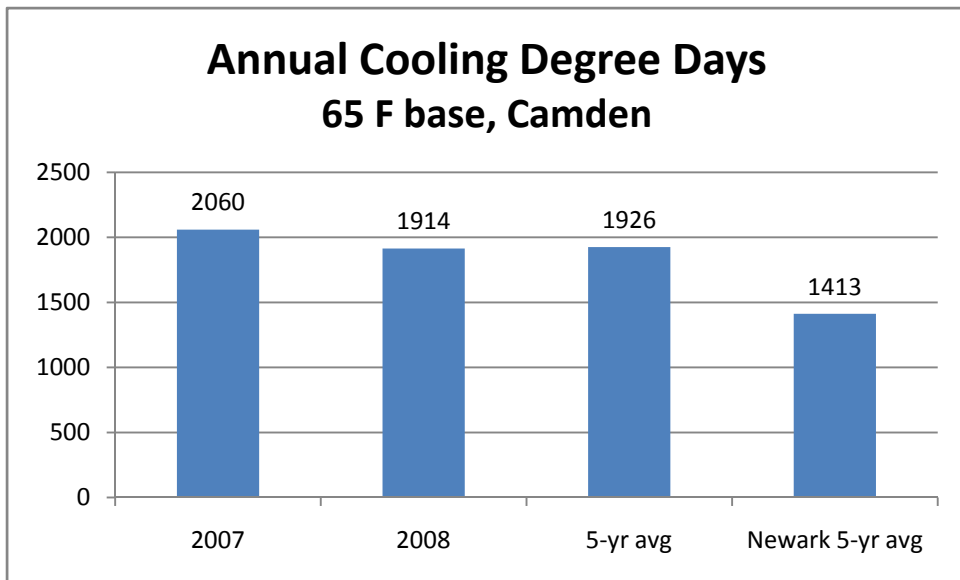
**Fig 47: Preliminary Natural Gas Intensity Comparisons for the Whole Building**



**Fig 48: Preliminary Electricity Intensity Comparisons for the Whole Building**



*Fig 49: Heating Degree Day Comparisons*



*Fig 50: Cooling Degree Day Comparisons*

## Climatic Variation

Natural gas and electricity use in buildings are strongly influenced by climatic conditions. A common reason why actual and design performance differ is that actual climatic conditions may differ from those assumed during design. This appears to be the case for the Tech Center.

Fig 49 shows the annual heating degree-days for the Camden<sup>27</sup> location in 2007, 2008, and a 5-year average. Both 2007 and 2008 had more heating degree-days than average (4% and 1%, respectively), which should have increased natural gas use relative to the design conditions which are based on historical averages. However, natural gas use is *less* than expected.

Fig 50 shows the annual cooling degree-days for the Camden location in 2007, 2008, and a 5-year average. The year 2007 had 7% more cooling degree-days than average, while 2008 had 1% fewer. However, electricity use is *more* than expected in both years.

Figures 49 and 50 also show the 5-year average design heating and cooling degree-days for Newark, New Jersey, which is where the pre-construction modeling done for the LEED submittal assumed the building would be located. A comparison of the design climate conditions shows that Camden has 18% fewer heating degree-days and 27% more cooling degree-days than Newark. Both the direction and magnitude of these differences matches the discrepancy in actual vs. modeled natural gas and electricity use. Thus, the substantial difference in the general climate in the actual location compared to the modeled location explains a substantial part of the differences in energy consumption.

## Design Changes

No building is ever built exactly according the initial design vision. Budget constraints force design changes, unforeseen conflicts arise, desired equipment and materials are no longer available, or the contractor identifies an alternative way to accomplish the design intent. For the Tech Center, the modeled As-Designed scenario differs from what was actually built in one notable way from an energy perspective: the actual building includes an electric pre-heater for the rooftop outside air handling unit, rated at 444 kW. The electric heater (which is included in the modeled Budget scenario) is estimated to add 4.7 kWh/SF-

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<sup>27</sup> Camden degree day data are proxied by a weather station located at Port Jefferson in Philadelphia, about 3 miles from the Tech Center site.



yr to the building's energy intensity.<sup>28</sup> This suggests that the electricity intensity in the As-Designed modeling scenario is about 20% too low, given the actual design. The natural gas intensity should be correspondingly reduced to reflect the substitution of electricity for natural gas in heating.

### Occupant Behavior

Humans use buildings in ways that designers do not fully anticipate. Occupants may use different equipment than predicted, their schedules may vary, and their preferences for light, thermal comfort, and other factors may diverge from design targets. A particularly notable problem in recent years is the increase in plug loads in buildings. Occupants are bringing in more computers, printers, copy machines, and other electricity-using devices than ever before. At the Tech Center, both the common area (core & shell) and the tenants' electric bills are higher than one would anticipate based on historical data such as CBECS. Looking only at non-common area electricity use, and removing the vacant 5<sup>th</sup> floor<sup>29</sup> from the occupied floor area, the electricity intensity of the tenanted areas is 14.5 kWh/SF-yr. Lights in the tenant areas are calculated in the LEED submittal to use 4.4 kWh/SF-yr. The residual that can be attributed to plug loads and fan-coil units is 10.1 kWh/SF-yr. CBECS estimates plug loads for typical existing buildings with a mix of uses similar to the Tech Center to be 4.6 kWh/SF-yr. Yet  $(10.1 - 4.6 = 5.5)$  5.5 kWh/SF-yr seems high for fan-coil units. So it is possible that plug loads are in fact higher than what CBECS reports because occupants are using more electricity-intensive equipment now than in 2003 when that survey was conducted.

### Startup Transients

The Tech Center is a complex building with systems that need tuning and balancing in order to perform well. As part of the LEED certification process, the building underwent commissioning to ensure that its mechanical systems were operating smoothly. The commissioning report identified several items and it appears that most were dealt with promptly. Nevertheless, it is typical for the first few years of a building's life to represent a learning period, as operating personnel learn how to optimize its systems. The Tech Center

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<sup>28</sup> The Trane Trace model output included in the LEED submittal estimates that the electric pre-heater uses 470,188 kWh/year. In a 98,225 square foot building, this equals 4.7 kWh/SF-yr.

<sup>29</sup> At the time that the calculations were performed in 2010 the 5<sup>th</sup> floor was vacant, now as of 2011 it is 50% occupied.

changed O&M contractors in the 2007-2008 period, so this learning process may have been extended. This may have contributed to higher energy intensities during that period, although it is no more than speculation.

A second startup transient has to do with the fact that tenants have moved in relatively slowly, in part due to the financial crisis and recession, which slowed real estate transactions and business growth worldwide. The building's first tenant moved in during 2006, and more followed each year, but as of this writing in 2011 the building remains 10% vacant<sup>30</sup>. A high vacancy rate would be expected to reduce energy use.

### Adjusted Energy Intensities

Based on the factors just discussed, it is reasonable to revise the energy intensities to reflect our better understanding. Figures 51 and 52 show adjusted energy intensities.

Both of the pre-construction, modeled scenarios (“As-designed”, “Budget”) are adjusted to account for, first, the average degree days at the Camden location relative to Newark (which had been assumed in the models), and second, for the degree days measured during the actual utility billing period of July 2007 through June 2008 relative to historical averages. The net changes are substantial, yielding 16% fewer HDD and 46% more CDD. Because the Trane Trace modeling deck used initially has been lost, we perform an approximate, spreadsheet-based adjustment by decreasing space heating (boiler, electric unit heater) energy use and increasing space cooling (chiller) energy use in direct proportion to the change in degree days. The resulting impacts on overall natural gas and electricity intensities are visible in Figures 51 and 52, respectively. Now the actual natural gas intensity matches the modeled as-designed value, although the actual electricity intensity remains substantially higher than modeled during design.

A second major adjustment is to include the electric pre-heater that is installed in the outside air handler that is mounted on the roof. This was not included in the modeled design, which relies entirely on the heat recovery wheel and terminal re-heating to provide space heat. Adding the electric pre-heater has the effect of shifting some of the heating load from the natural gas-fired boilers to electricity. Using the spreadsheet adjustment calculation described previously for degree days, we shift 40% of the heating load to the electric pre-heater, thereby matching the electricity consumption modeled in the Budget scenario which

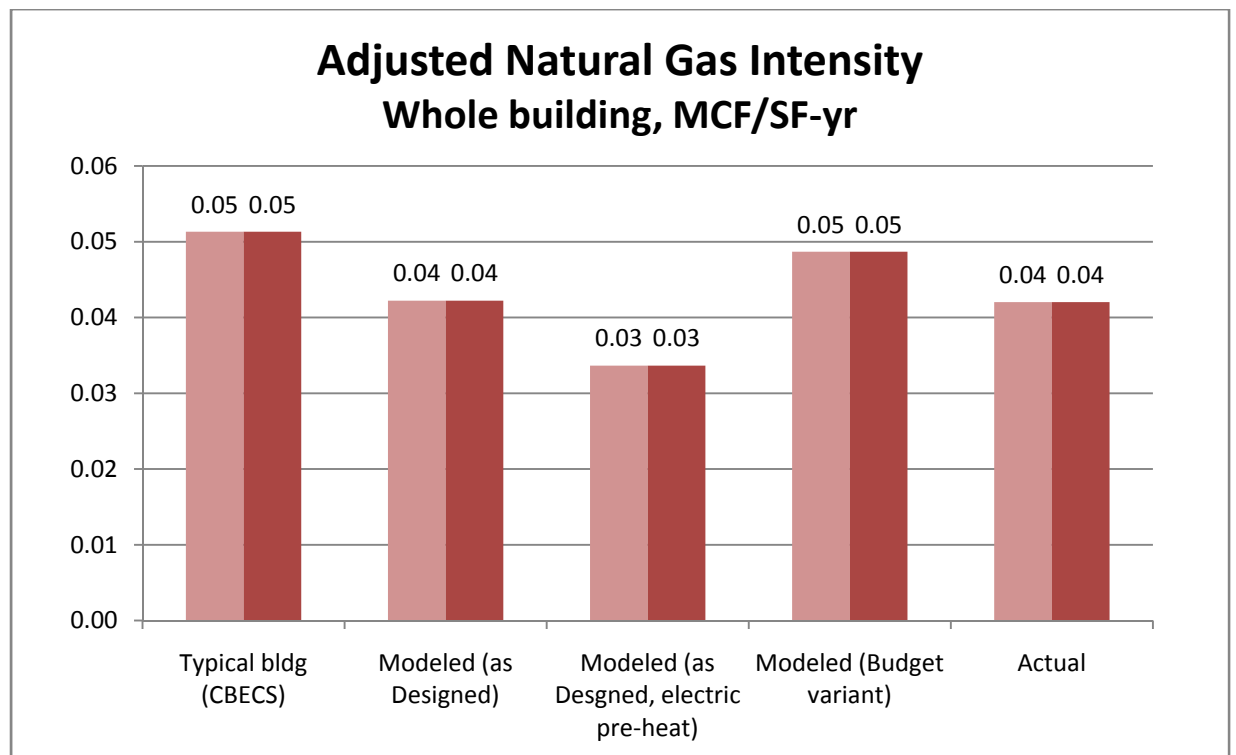
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<sup>30</sup> Personal communication with Steven Martorana, NJEDA, 2/28/2011

includes an electric pre-heater. The result is a new scenario that uses 40% less natural gas and 58% more electricity for space heating and cooling purposes. The change in overall natural gas and electricity intensities between the as-designed and as-designed including electric pre-heat is -14% and +16%, respectively. Now the actual natural gas intensity is 25% higher than the modeled as-designed case, which was adjusted to have electric pre-heat, but the actual electricity intensity almost matches the adjusted design intent. It is important to note that electricity cost comprises 85% of annual energy costs for the whole building.

The actual natural gas intensity of the building is approximately 20% lower than the adjusted budget case, whereas the actual electricity intensity is 8% lower than the adjusted budget case.

We lack an empirical basis to do further adjustments to reflect occupant behavior (especially plug loads) and startup transients (especially the effects of operator actions). The adjusted energy intensities shown in Figures 51 and 52 suggest that the Tech Center’s energy use is within the normal range of similar buildings and its designers’ intent.



**Fig 51: Natural Gas Intensity Comparisons Adjusted for Climate**

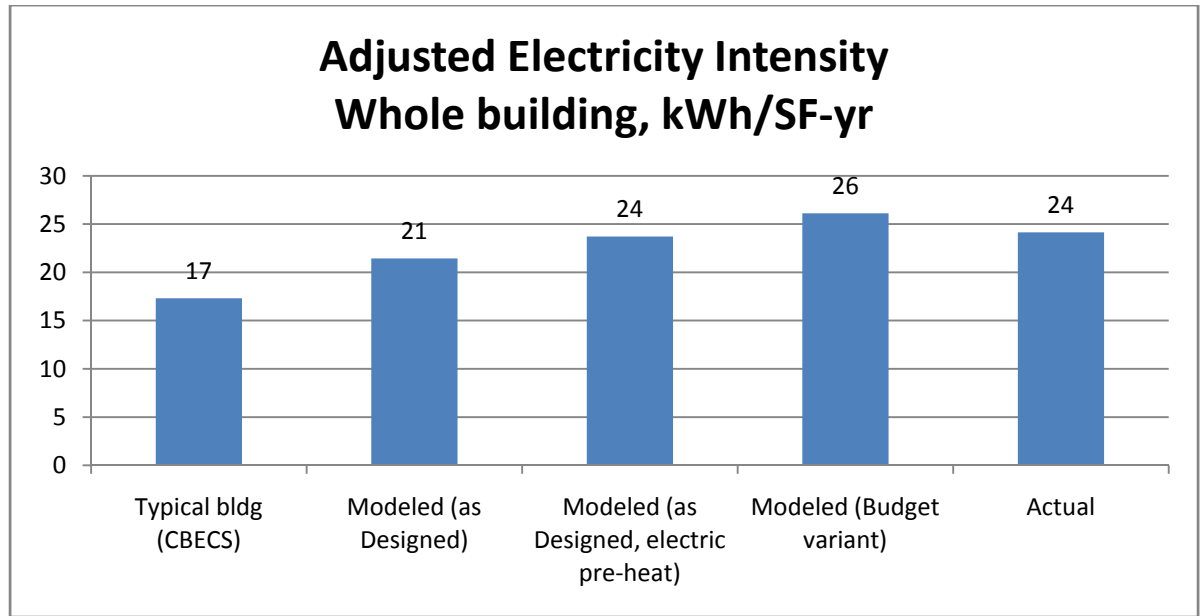


Fig 52: *Electricity Intensity Comparisons Adjusted for Climate*

### Conclusions and Recommendations for Further Research

Overall, it appears that the Tech Center’s core and shell are performing well, and that it is a relatively energy-efficient design. Tenants’ plug loads may be an increasing problem that could offset the savings achieved by the greener design of the fundamental building systems.

Future research should directly measure plug loads instead of treating them as a residual. It would also be valuable to understand how well the heat recovery wheel is performing by directly measuring the amount, direction, and timing of heat transferred. Finally, it would be interesting to investigate the net energy and productivity benefits of the large amount of window area that graces the Tech Center.

## *Water Use*

### **Introduction**

The EDA building's water efficiency features include low-flow fixtures (water closets, urinals, lavatories and sinks), no outdoor irrigation, and only make-up water for the closed-loop recirculating water systems for cooling and heating. The cooling system has redundant chillers to generate recirculating chilled water and the heating is supplied by natural gas-fired boilers to provide recirculating hot water for the building heating.

### **Methodology**

The building's actual water consumption was obtained from the quarterly utility bills from 12/19/06 to 6/05/09. The water consumption based on the LEED rating system was determined for two cases, a baseline (i.e., Budget) and a Design case. The Budget case assumes conventional fixtures based on the Energy Policy Act of 1992 and the Design case low-flow fixtures that are installed in the EDA building. For comparison with the literature, data from field studies of five conventional commercial office buildings ranging from 8,800 to 186,000 sq ft. (Dziegielewski et al., 2000) are presented.<sup>31</sup>

The per-capita water consumption of the Tech Center is based on 240-290 employees, the per-square foot water consumption on the square footage of the occupied floors (four floors: 78,580 sq ft.) and the daily water consumption for 365 days and 260 working days, respectively.

### **Results and Discussion**

The average daily water consumption of the building in the more recent billing period (9/15/08-6/05/09) was 31% lower than the water consumption of the previous year (9/17/07-6/16/08) (1230 vs. 1770 gallons/working day) (Fig 53). The elevated water consumption in the previous year is caused by elevated water consumptions in water billing

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<sup>31</sup> Dziegielewski, B.; Kiefer, J.C.; Opitz, E.M.; Porter, G.A.; Lantz, G.L.; DeOreo, W.B.; Mayer, P.W.; Nelson, J.O. (2000). *Commercial and Institutional End Uses of Water*. AWWA Research Foundation, Denver, CO.

quarters ending September 2007, December 2007 and March 2008 (Fig 54). The reasons for the elevated water consumption are unknown.

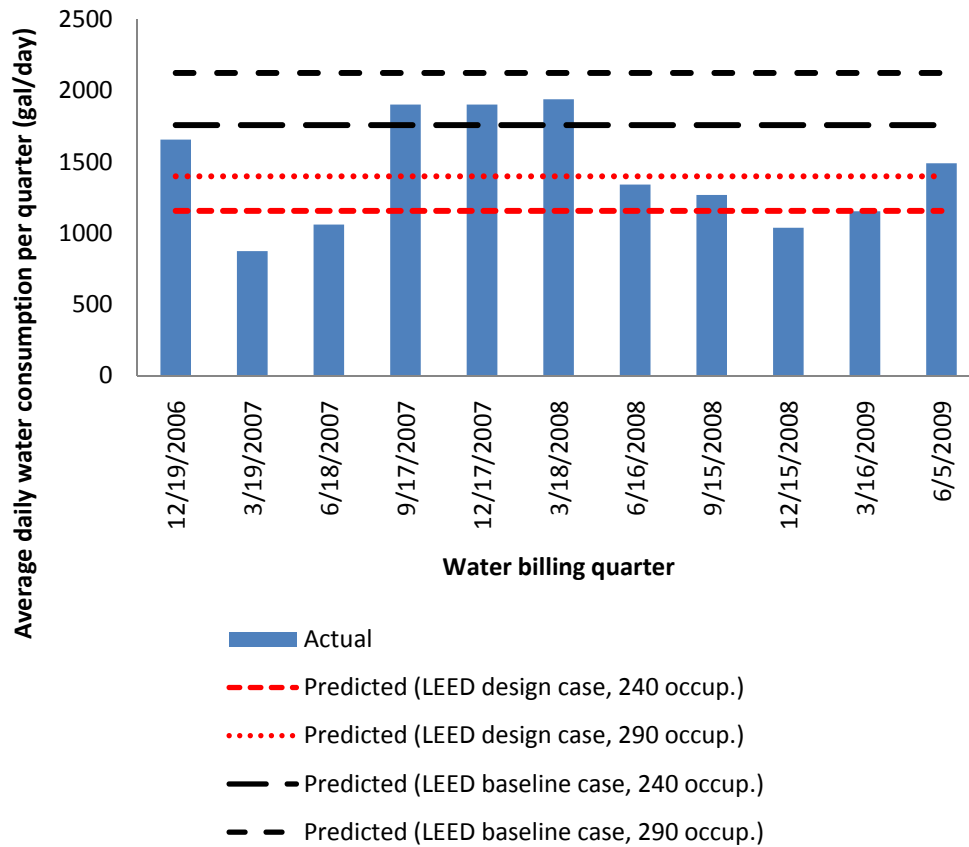
Annual water consumption (9/15/08 – 6/05/09) is in the same order of magnitude as the water consumption predicted for the LEED Design case (Fig 53). However, a more accurate determination of the number of employees is needed for a more accurate comparison between the predictions for the LEED Design case and actual water consumption. In addition, predictions for the LEED Design case only account for domestic water use. Therefore, it might be possible that the water consumption for the LEED Design case underestimates the building’s water consumption. Other process water uses (e.g., laboratory) should be assessed to estimate their contribution to overall water consumption. In addition, the actual water consumption should be assessed more long-term.

By way of further comparison, Dziegielewski et al. (2000) determined the water consumption for five case study office buildings ranging between 519 and 15,500 gallons/working day (Fig 53). The lower end of the range is the water consumption of a building with water efficient fixtures and is below the water consumption of the Tech Center building. The authors note that part of the variability of water consumption of the case study buildings might be due to the wide range of building sizes.

Unit	Actual consumption based on quarterly billing records		Water consumption based on LEED certification		Dziegielewski et al., 2000 Field study
	9/17/07 – 6/16/08	9/15/08 – 6/05/09	Baseline case, Energy Policy Act of 1992 assumptions	Design case	
10 <sup>3</sup> gal/year	461	320	457 - 552	301 - 364	135 -4035
gal/day	1260	877	1253 - 1514	825 - 997	370 - 11000*
gal/work day ‡	1770	1230	1759 - 2125	1158 - 1400	519 - 15500*
gal/cap*work day ‡	6.12 - 7.39	4.24 - 5.13	7.33	4.83	2.16 - 53.5*
gal/sf*year #	5.87	4.07	5.82 - 7.03	3.83 - 4.63	4.07 - 22.86
gal/10 <sup>3</sup> sf*day #	16.1	11.2	15.9 - 19.3	10.5 - 12.7	11.2 - 62.6*
‡ based on 260 working days, # based on 78,580 sf * calculated based on given information					

**Fig 53: Water Consumption of the Waterfront Technology Center**





**Fig 54: Average daily water consumption of building and predicted daily water consumption based on LEED design case and LEED base case assumptions.**

## Life Cycle Performance

### *Life Cycle Cost (LCC) Analysis*

#### **Introduction**

In order to evaluate further the performance of the Tech Center, we performed a Life Cycle Costing (LCC) analysis. Life cycle cost (LCC) analysis is an economic tool used to examine the total costs associated with a building from its construction to its demolition. This “cradle-to-grave” analysis incorporates not only the initial costs but also the lifespan operating costs, so that a more complete picture of total cost can be obtained. LCC analysis is useful in the context of green building because green features characteristically have higher up-front costs but recover some or all of that cost over a certain period of time. The LCC therefore helps to determine the feasibility of such features from an economic standpoint. More complex LCC analyses can be performed on virtually all aspects of a building; this assessment is concerned only with the factors affecting energy consumption and cost.

#### **Methodology**

In order to perform the LCC analysis, the as-built subject building is compared using both the modeled design case and the budget design case buildings. Both utility consumption data and the capital costs for building features relating to energy consumption (electrical, HVAC, exterior walls, glazing, roof) are required for each building in the comparison. For the Tech Center, utility data and capital cost data were acquired from the NJEDA. The costs for the budget case building are modeled from RSMeansCostWorks Online as well as industry standard building costs, and are verified by engineers and building consultants.

A component part of an LCC is a Net Present Value (NPV) analysis. Net present value refers to the total present value of the lifetime costs associated with a particular project. Aside from the environmental benefits of energy consumption reduction, it is expected that a decrease in the operational costs over a building’s lifetime will help mitigate the higher up-front costs associated with energy-efficient green buildings. A positive NPV relative to the budget case represents the lifetime savings of the energy efficient building.

Net present value, therefore, is an extremely useful economic tool in determining the true value of energy saving features in a building.

Once the energy consumption values were obtained for the two building designs, they were tabulated in an LCC spreadsheet adapted from one developed by the Rutgers Center for Green Building for prior projects. The budget case building was used as the “base” model for comparison purposes. The as-built Tech Center and the modeled design case were evaluated on discrete bases as well as relative to the budget case. All analyses are reported on a per-square-foot basis. Note that these analyses exclude tenants’ costs; they focus on the core and shell.

Finally, we performed several sensitivity analyses. A sensitivity analysis examines the effect that different factors have on the relative NPVs of the represented projects. In this LCC analysis, there are three factors for which we ascribe variable values: future energy costs, the discount rate, and building lifespan. Future energy costs were set to 75% and 150% of their projections from the DOE Annual Energy Outlook 2009.<sup>32</sup> We use three different values for the discount rate. The primary NPV analysis uses a 7% discount rate – arguably pretty generous in today’s economic climate, while the low discount rate of 5.04% represents the 30-year average mortgage rate with points from Freddie Mac as of September 17, 2009. A more aggressive discount rate of 12% was also employed. Building lifespan for the primary NPV analysis is assumed to be 30 years, and 15-year and 50-year lifespans are substituted in the sensitivity analyses.

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<sup>32</sup> *DOE Energy Outlook Handbook 2009*, Tables A8 and A13, pp. 127 and 136.

## Results and Discussion

Following are the results of the primary NPV analysis as well as the sensitivity analyses.

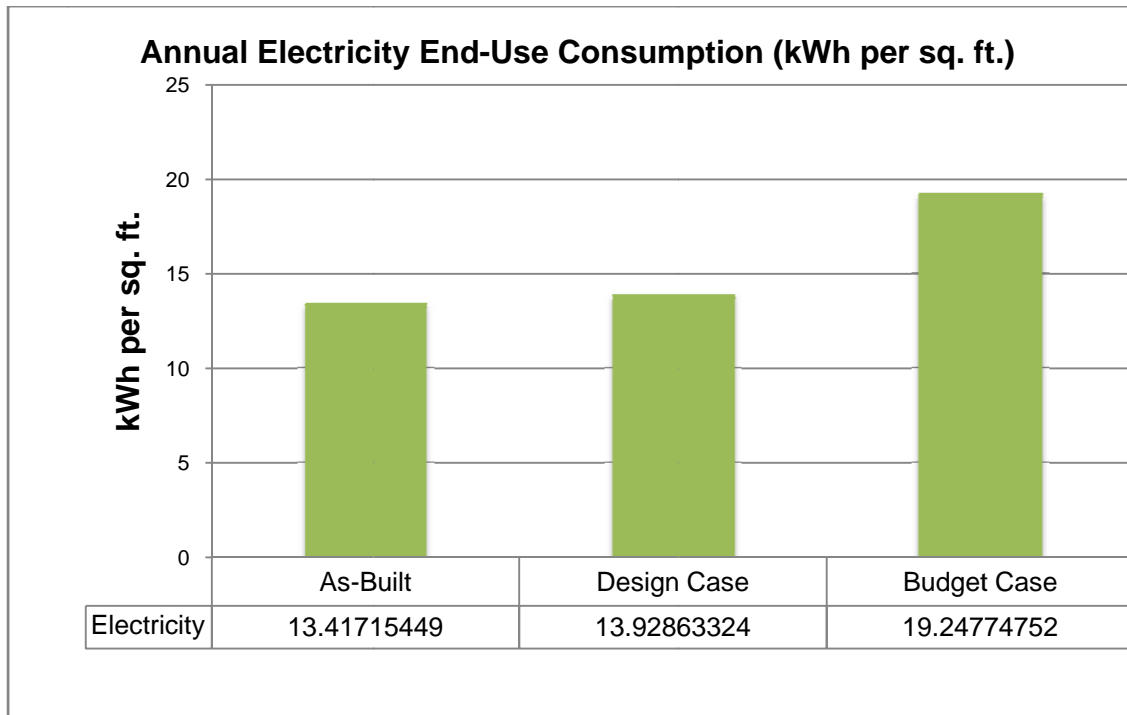


Fig 55: Annual Electricity End-Use Consumption (kWh per sq. ft.)

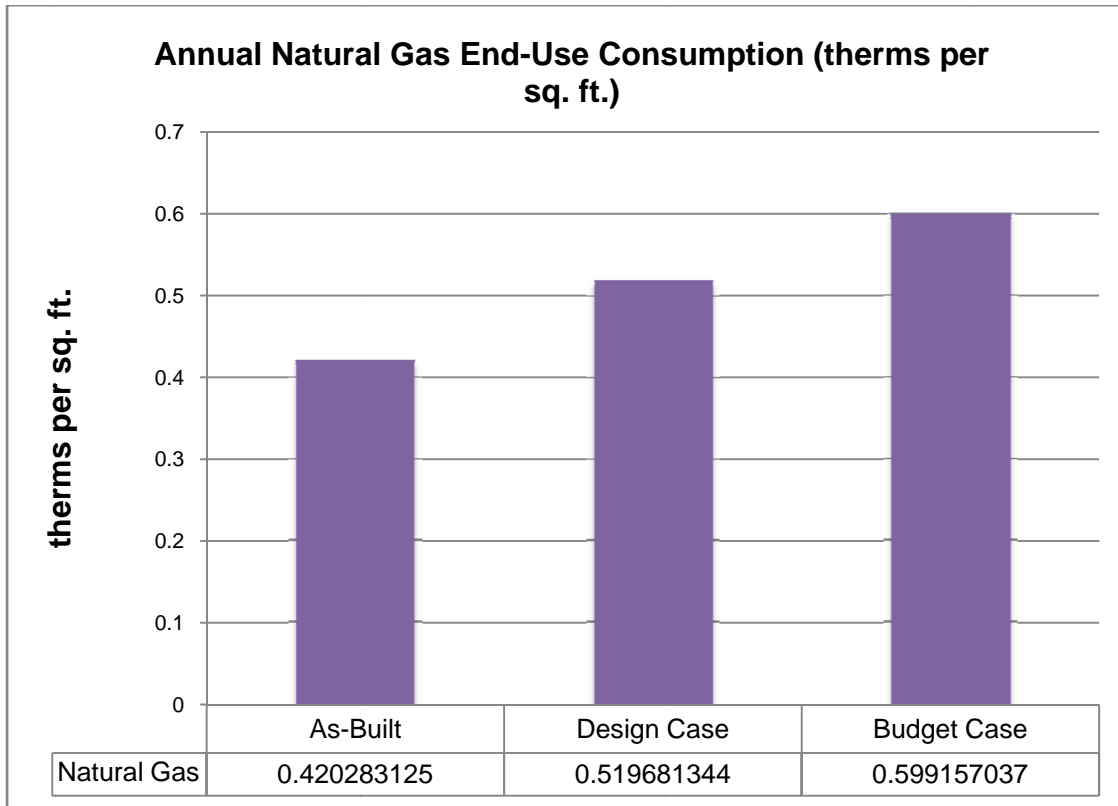
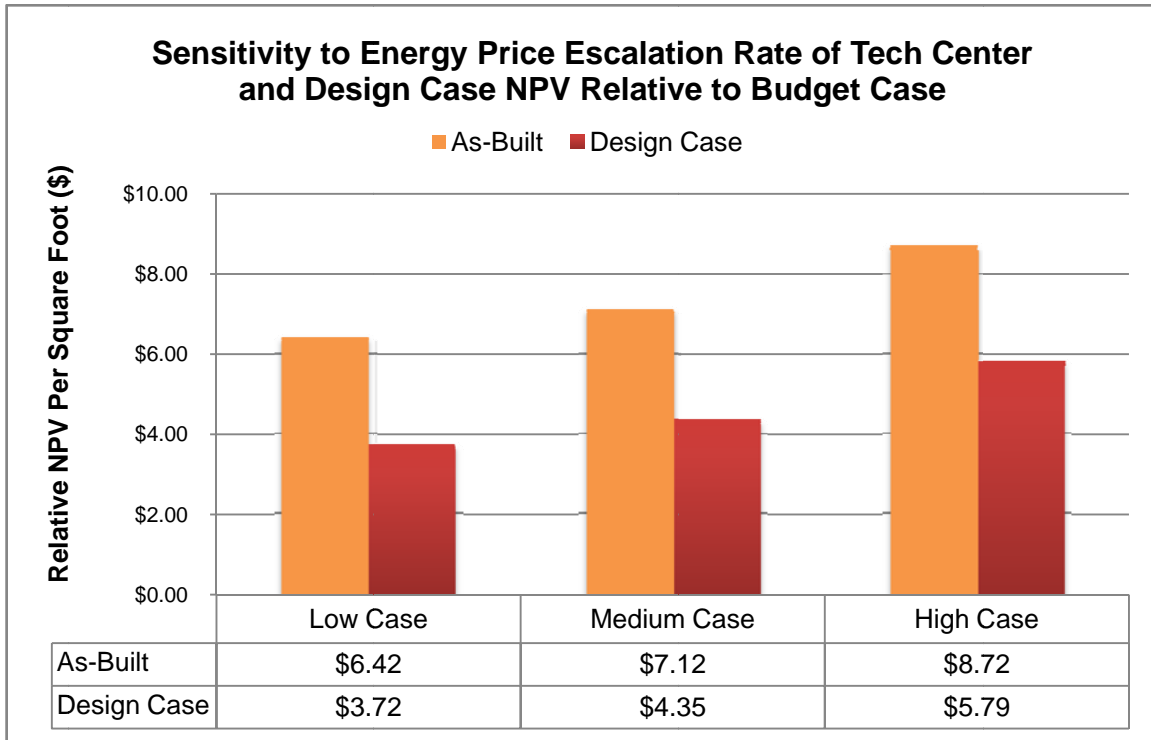


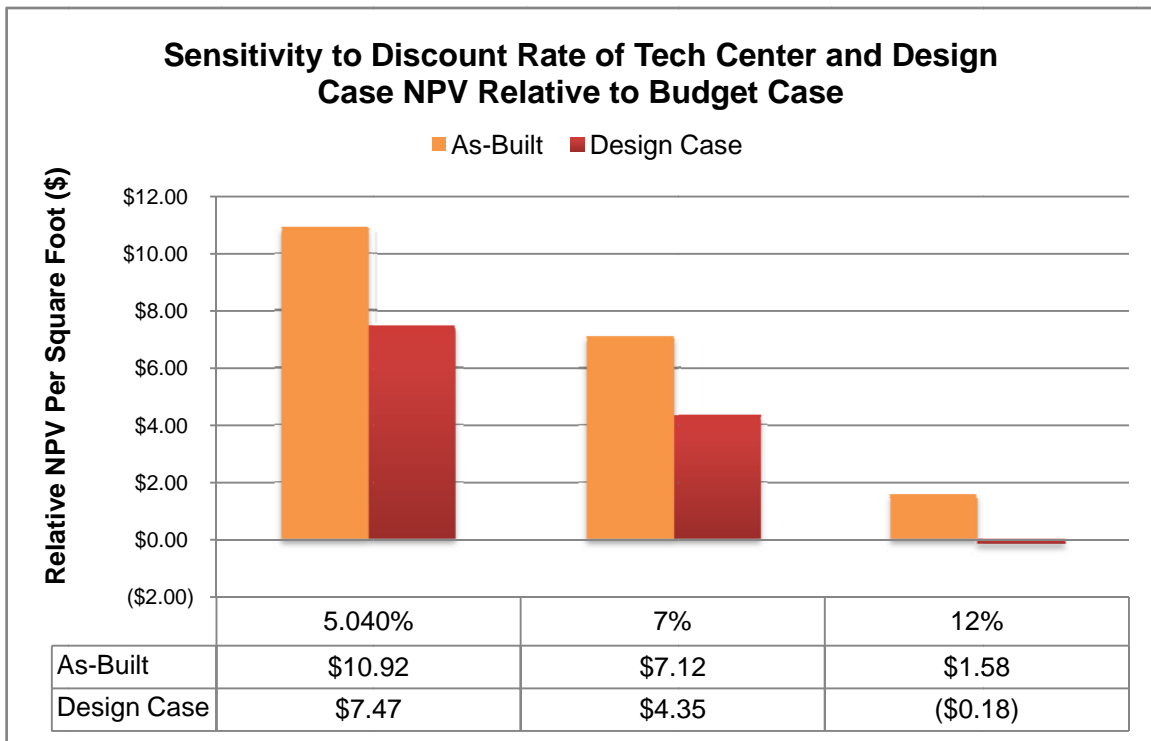
Fig 56: *Annual Natural Gas End-Use Consumption (therms per sq. ft.)*

Building	Initial Cost Per Square Foot	Initial Cost Per Square Foot, Relative to Budget Case	Net Present Value (NPV) Per Square Foot	NPV Relative to Budget Case
As-Built	\$46.46	\$7.52	(\$41.35)	\$7.12
Design Case	\$46.46	\$7.52	(\$44.12)	\$4.35
Budget Case	\$38.94	\$0.00	(\$48.48)	\$0.00

Fig 57: *Net Present Value (NPV) Analysis*

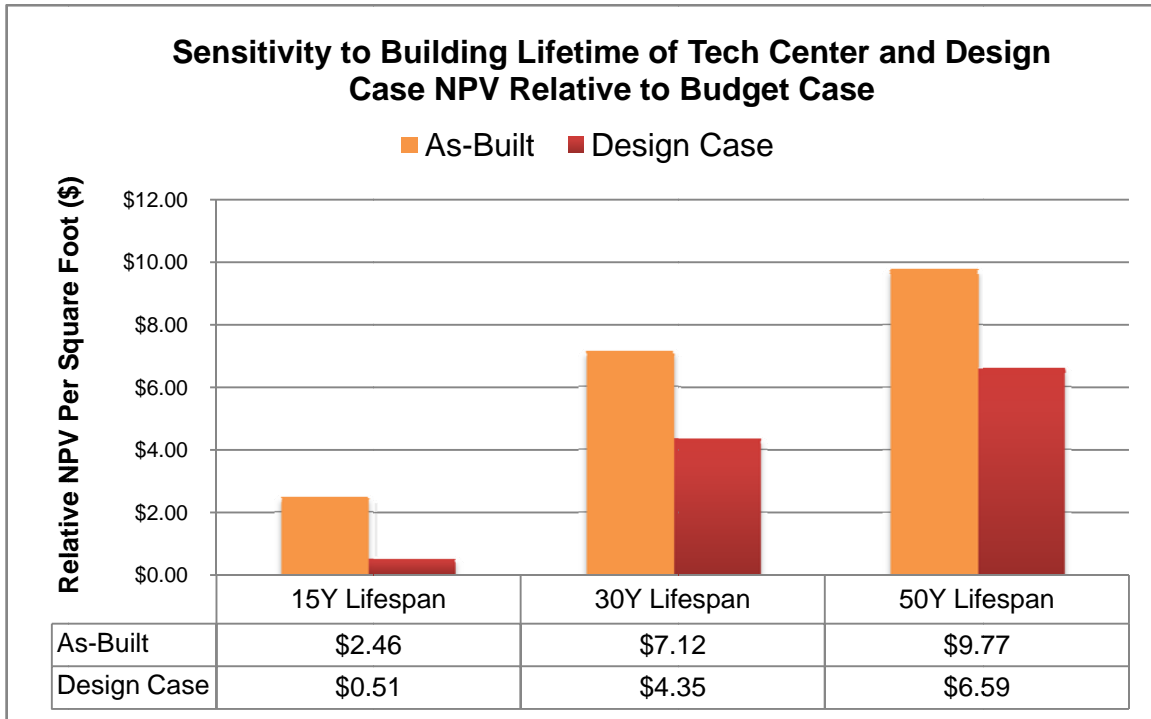


**Fig 58: Sensitivity to Energy Price Escalation Rate**



**Fig 59: Sensitivity to Discount Rate**





**Fig 60: Sensitivity to Building Lifetime Estimate**

The completed LCC analysis presents several noteworthy results. First, per-square-foot natural gas and electricity usage were both highest in the budget case, followed by the design case, and lowest in the as-built case. The design case used 27.6% less electricity than the budget case, while the as-built case used 30.3% less (Fig 55); the same figures for natural gas consumption were 13.3% and 29.9%, respectively (Fig 56).

Based on the primary NPV analysis (using current energy prices, a building lifespan of thirty years, and a discount rate of 7%) the as-built Tech Center has a positive NPV relative to the budget case of \$7.12. This represents a savings of \$7.12 per square foot compared to the budget case over the 30-year lifespan of the building. This is higher than the design case’s relative NPV of \$4.35 (Fig 57).

The as-built Tech Center similarly outperformed the design and budget cases in all sensitivity analyses; in fact, for each of the three, the as-built Tech Center maintained a positive NPV relative to the budget case. Energy escalation rate (Fig 58) had the smallest effect on the relative NPVs of the as-built Tech Center, ranging from \$6.42 at 75% of the escalation rate to \$8.72 at 150%. Examining the discrete NPV/sq. ft., the as-built Tech

Center (a range of \$5.30) was less sensitive to changes in the energy escalation rate than the budget case (a range of \$7.61). This makes logical sense, as the more energy a building consumes, the more it will be affected by changes in energy prices.

Changes in the discount rate (Fig 59) had the greatest impact on the relative NPVs of the buildings. The relative NPV of the Tech Center ranged from \$1.58 at a 12% discount rate to \$10.92 at a 5.04% discount rate. Again, the Tech Center was less sensitive to changes in the discount rate than the budget case building (range of \$21.58 for the Tech Center; range of \$30.92 for the budget case).

Projected lifespan of the buildings (Fig 60) also had a significant impact on the relative NPVs. Here, the relative NPV of the as-built Tech Center was \$2.46 for a 15-year lifespan and \$9.77 for a 50-year lifespan.

## **Conclusion**

The life cycle cost analysis performed here shows that, when compared to the budget case modeled building, the reduced energy consumption of the as-built Tech Center results in a positive NPV relative to both the design and budget cases; the positive relative NPV is maintained across all sensitivity analyses. This suggests that the increased capital costs for the high-performance fixtures likely will pay off, even in the relatively short term.

## *Environmental Impacts and Avoided Infrastructure Cost Analysis*

### **Introduction**

Existing studies on green building performance show that when compared with conventional building practices, green buildings demonstrate reductions in energy use by 30%, carbon dioxide emissions by 35%, water use by 50%, and construction waste by 50% or more.<sup>33</sup> As they become more prevalent, green buildings may result in lower impacts to centralized (municipal or regional) infrastructure systems. In this study, we analyzed the extent to which this may be discerned with regard to energy and water.

### *Energy Infrastructure*

Energy infrastructures, especially electricity and natural gas supply and distribution systems, are long-lived investments. The median size-weighted age of currently operating coal-fired power plants in the United States is 35 years,<sup>34</sup> and many transmission and distribution system elements in New Jersey are even older. Any demand-side investment that delays the need to invest in new supply and distribution capacity has the potential to deliver both private and social value. Likewise, any demand reduction that reduces pollutant emissions and other unintended consequences of energy production has value to society. One challenge in quantifying these benefits is in determining when both the operating and capacity-avoidance benefits apply. To the extent that green buildings save energy, they always reduce the operational demands on infrastructure, but the extent to which they delay the need for new capacity also depends on how much excess capacity exists. Thus it is common to refer to average (operational) and marginal (capacity-avoidance) benefits.

Green buildings often use less energy than conventional buildings of the same vintage.<sup>35</sup> However, we simultaneously find that typical new buildings are more electricity intensive than the typical existing building, while the natural gas intensity is slightly less, and overall

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<sup>33</sup> U.S. Green Building Council Research Committee. 2007. *op. cit.*, p.13.

<sup>34</sup> Newcomer, A.; Blumsack, S.; Apt, J.; Lave, L.B.; Morgan, M.G. 2008.

Electricity Load and Carbon Dioxide Emissions: Effects of a Carbon Price in the Short Term, *Proceedings of the 41st Annual Hawaii International Conference on System Sciences*, Volume , Issue , 7-10, Pp.179 – 179.

<sup>35</sup> U.S. Green Building Council Research Committee. 2007. *op. cit.*, p.13.

energy intensity is about the same.<sup>36</sup> Figures 61, 62, and 63 illustrate these trends for commercial buildings in the Mid-Atlantic region of the United States. This is mostly due to higher plug loads, lighting and cooling, which increase electricity intensity, and lower space heating, which reduces natural gas intensity.<sup>37</sup> In our specific comparison of the Tech Center to a conventional new building, the result is that the Tech Center is both less electricity intensive and less natural gas intensive. In other words, this green building makes things less bad at the margin and delays the time period before which new infrastructure investments are needed. At the same time, this green building puts less strain on existing infrastructure operations by requiring less delivery of electricity and natural gas.

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<sup>36</sup> Energy Information Administration, U.S. Department of Energy. 2006. Commercial Buildings Energy Consumption Survey 2003, Tables c7a, c17a, and c27a, showing energy intensity by age of building in the Mid-Atlantic region. The average year of construction for a square foot of commercial building in this region is 1958. Retrieved on February 4, 2010 from

[http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed\\_tables\\_2003/detailed\\_tables\\_2003.html#enduse03](http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#enduse03).

<sup>37</sup> Energy Information Administration, U.S. Department of Energy. 2006. Commercial Buildings Energy Consumption Survey 2003, Table e2a, showing energy intensity by end use. Retrieved on February 4, 2010 from

[http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed\\_tables\\_2003/detailed\\_tables\\_2003.html#enduse03](http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#enduse03).

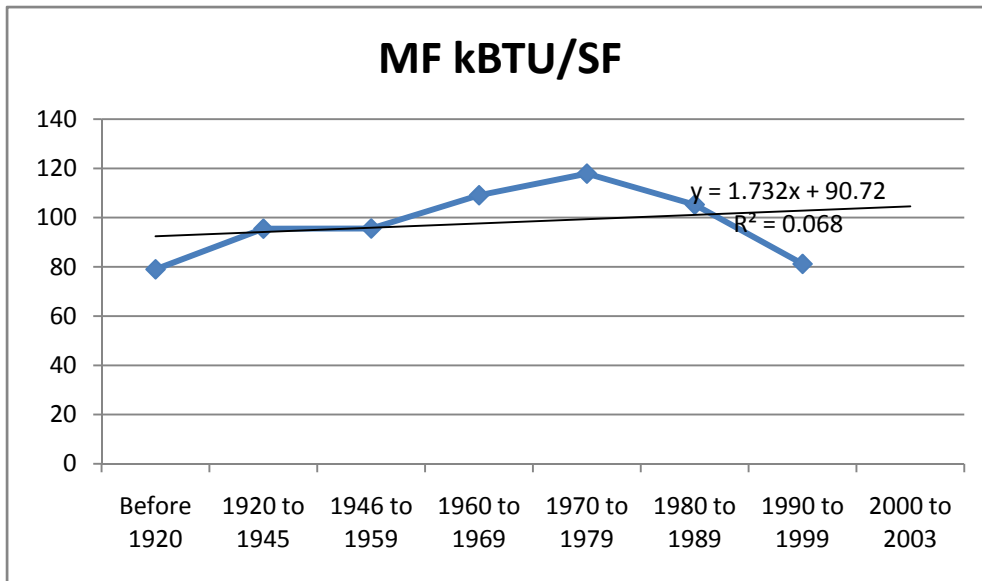


Fig 61: Multi-fuel energy intensity of commercial buildings in the Mid-Atlantic region by year built. Note that the typical building (weighted by floor area) was built in 1958.

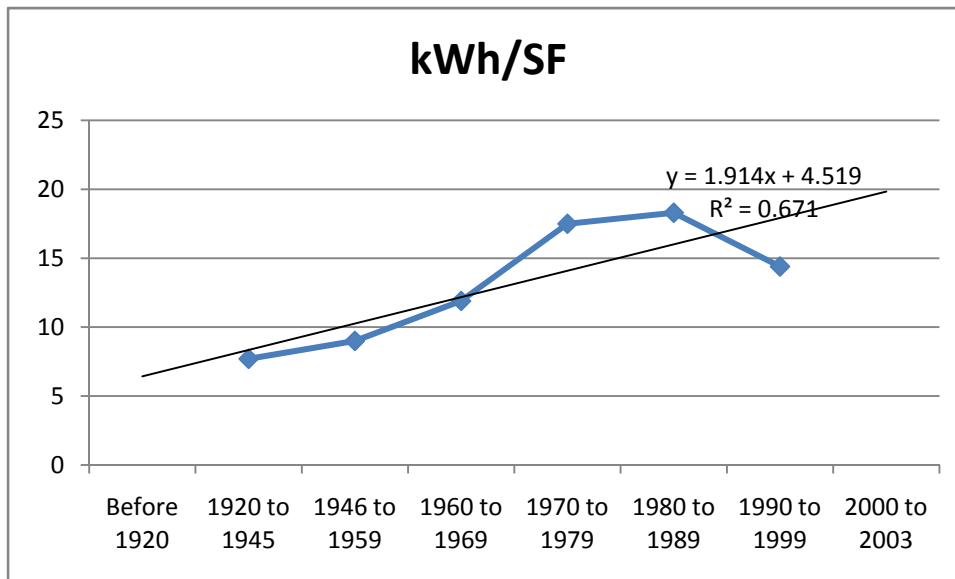
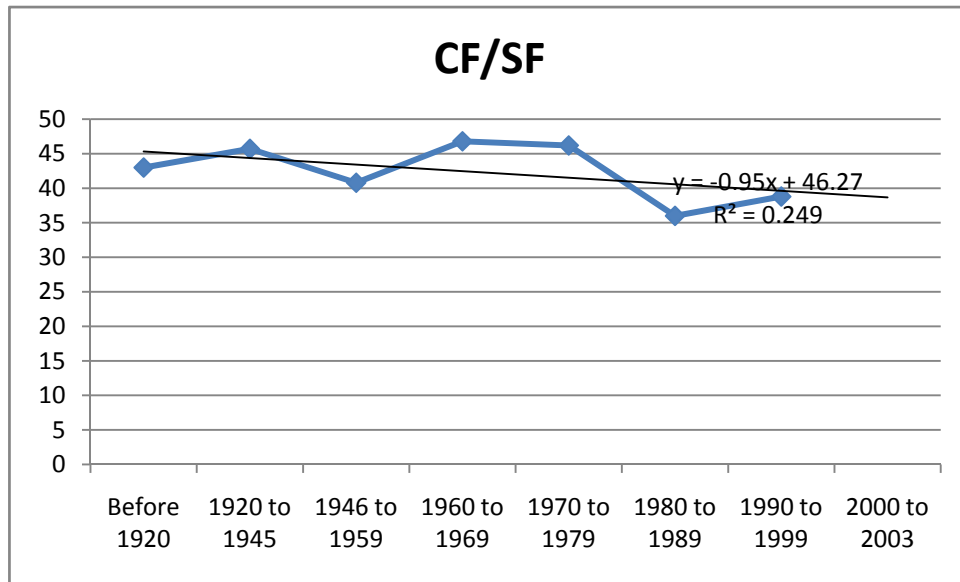


Fig 62: Electricity intensity of commercial buildings in the Mid-Atlantic region by year built. Note that the typical building (weighted by floor area) was built in 1958.



**Fig 63: Natural gas intensity of commercial buildings in the Mid-Atlantic region by year built. Note that the typical building (weighted by floor area) was built in 1958.**

### Water Infrastructure

Water and wastewater piping systems have a life span of 50-100 years. In many eastern cities in the US the infrastructure is 200 years old. Replacing the infrastructure requires large investments. Furthermore, the price paid by consumers for water does not include the total costs for water supply. In the developed and developing world only about 35% of the total costs are covered (Renzetti et al., 1999).<sup>38</sup>

If green buildings implement water conservation (i.e., water efficient fixtures and appliances, reuse water, reduced outdoor irrigation), there is the potential to reduce water supply and wastewater treatment infrastructure costs (i.e., facility and piping construction and expansion). However, avoided costs are only expected to have an effect when water efficient fixtures, appliances and practices are implemented on a large scale and not just in one green building. Concerning wastewater treatment, however, it also needs to be taken into account that the wastewater will be more concentrated. Many unit processes in the

<sup>38</sup> Renzetti, S. 1999. Municipal water supply and sewage treatment: costs, prices, and distortions," *Can. J. Econ.*, 32 (3), 688-704.

wastewater treatment facility are sized based on the pollution load and not the wastewater volume and therefore the cost reduction will not be proportionate. While there is a general consensus that green buildings avoid water infrastructure costs, there is only limited information about the actual avoided infrastructure costs. Reasons might be that the costs are case-specific and that there are only a few green buildings.

Assuming water conservation in green buildings is implemented on a large scale, Kats et al. (2003) estimated \$500-750/acre-foot (af) of conserved water for California and in addition \$300/acre-foot for reduction of leaks in the water distribution system.<sup>39</sup> This included only the immediate costs for water conservation and not the long-term marginal cost for water supply and wastewater treatment expansions and environmental damages. Including the later costs, the authors estimated 20-year present value marginal costs for water supply and wastewater treatment to public agencies of \$14,332/af.

## **Conclusion**

In conclusion, green buildings are expected to reduce infrastructure cost. Green buildings reduce operating costs of energy and water supplies, allow them to operate more efficiently in cases where demand can be shifted off peak, and postpone the need for new capacity.

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<sup>39</sup> Kats, G., Alevantis, L, Berman, A., Mills, E. and Perlman, J. 2003. *The Costs and Benefits of Green Buildings*. Report the California's Sustainable Building Task Force. Capital E, Washington, DC.



## Building Occupant Satisfaction and Performance

### *Occupant Survey*

#### **Introduction**

Occupancy data is an integral component of developing an explanation of building performance. Surveys of building occupants can help to confirm and clarify findings in the areas of energy and water usage, and occupant satisfaction.

#### **Methodology**

The data from the EDA questionnaire is based on very few completed surveys provided by a self-selected sample from 2 organizations within the EDA facility (Tenant 1 & Tenant 2) and therefore *must be viewed as suggestive only*. In all, 27 valid surveys were returned. Of these, 18 came from Tenant 1 and 9 from Tenant 2. While the Tenant 2 respondents tended to have been employed by the company for a long period (mode = 4-10 years), Tenant 1 respondents were more recent hires. Most respondents were between 20 & 50 years old (mode 25-40) and came from a mix of job types and levels. Seventy percent of those responding were male.

#### **Results and Discussion**

Overall, this facility was *viewed very positively* by those who completed the survey, although there were some specific areas of concern.

Perhaps the most interesting information from the survey has to do with the response to the building as a green building. Most of the subjects indicated that they were aware of the concept of green buildings and most had a generally positive view of their value. However, many *did not seem aware* that this building was in any way special as green, and only 30% saw this building as “green.” In addition, the “greenness” of this building seemed to have no impact on the employees’ decisions to seek, take, or remain at their jobs.

The former result – lack of awareness of the green nature of the building – suggests that the developers and/or managers do not overtly advertise or trumpet this aspect of the facility design, and/or that there are no obvious features that visually stand out or appear so

unusual as to clearly suggest green design. The other finding – that employees did not seem influenced by the “greenness” – follows from the first, but may also reflect the economic realities of priorities in seeking work.

Overall, the environment was rated very highly. Almost all of the subjects (96.3%) were either very satisfied or satisfied with the overall design and appearance of this environment. Females were marginally more satisfied with the environment than were males. Almost all respondents (92.6%) saw the environment as clean, and were satisfied with this location (92.3%), as well as with furnishing & fixtures (91.3%), although women were slightly less satisfied than were men. Respondents were very satisfied with the common area (91.3%). Most were quite satisfied with their amount of workspace (87%). Most of those responding were highly satisfied with the overall level of comfort, view and daylight access. Lighting was not a problem. Most respondents seemed satisfied with the lightning, and did not report a concern about glare. When there was a need to adjust lighting most did so by using the blinds, adjusting their monitor, or adjusting the task lighting.

There were some areas of concern, however. Forty-seven percent (47%) of the respondents were dissatisfied or very dissatisfied with the building’s landscaping/outdoor space and 42.3% were dissatisfied or very dissatisfied with the location or convenience of recycling containers.

Privacy, too, seems to be an issue. Over half the subjects (54.6%) were dissatisfied or very dissatisfied with the level of privacy the office afforded (these findings are consistent with many studies of cubicle/open office environments). Privacy differed little by floor, but males seemed somewhat more bothered by lack of privacy than were females. Respondents from Tenant 1 were somewhat less satisfied with their levels of privacy than those from Tenant 2.

Many respondents (52.2%) were not satisfied with the level of noise. Those responding who worked with Tenant 1 seemed to have more problems with the noise than those from Tenant 2. Noise was more often cited more as work problem by those with outer perimeter windows and those with high partitions. Males seemed somewhat more bothered by noise than were females.

Respondents were generally happy with the adjustability afforded by the setting (78.2%) although those on the upper floor, those at Tenant 2 were less satisfied than others

(s). The most common items that were seen as adjustable in order to make the work setting more comfortable were the blinds (27.3%), desk lights (24.2%), and ambient light switches (24.2%).

Respondents indicated that they rarely put in requests for work orders in order to make the workplace more comfortable and when they did they were satisfied with the responses.

Temperature comfort and control seemed to be a concern with 47.4% of the respondents indicating that they were not satisfied with the thermal environment. The most common response to temperature problems was to make an adjustment in clothing. Only a few respondents reported adjusting the thermostat. Those with northern exposure seemed more likely to say they adjusted thermal comfort by using layers of clothing. Those on upper floor seemed more dissatisfied with temperature.

Air quality, though, was satisfactory for over 90% of respondents. Those in cubicles with low partitions have more air quality concerns. Most respondents indicated that the view outside and the view of nature had a very positive effect on their work.

## CONCLUSIONS AND NEXT STEPS

### Green Building Design & Practice

Quite often, builders and building owners base decisions on the upfront cost of materials and services. Yet these decisions may affect building performance over the entire life cycle of the building. This study takes a more holistic approach to building performance, looking at the environmental, economic, and human impacts of different building materials and design strategies. The case study and third party analysis give builders and their owners valuable insight into how environmental impacts, life-cycle costs, and human health issues factor into the building equation.

### Green Building Policy

The results of this case study and similar studies can be used to guide future policy-making regarding the construction of green buildings in New Jersey, and may prove useful to the U.S. Green Building Council's ongoing evaluation and revision of the LEED Standards.

### Future Green Building Research

There is strong evidence that green building – or at least aspects of it – constitutes a long-term trend and not a passing fad. As green building continues to mature, questions as to the performance of green buildings are becoming more common. A standardized set of metrics and routine data collection needs to be established as part of the growing practice of Post Occupancy Evaluation (POE). For green building practices to evolve, systems need to be put into place to track real-time and long-term trends, and to provide individual and collective feedback on the performance of green buildings. The notion that not all green buildings are alike and therefore that some may turn out to have more desirable performance characteristics than others, gives rise to a burgeoning area of research. This research will likely need to look at the performance of green building design features and technologies along a continuum and begin to better understand the interactions and tradeoffs between these different green elements. This case study is part of a series of case studies being conducted by the Rutgers Center for Green Building designed to fulfill this need.

# APPENDICES

## Appendix A – LEED Templates

 <b>LEED-CS</b>		<b>Waterfront Technology Center at Camden, LEED-CS® Pilot Project</b> <b>LEED-CS Certification Level: GOLD</b> <b>30 May 2006</b>		
<b>36 Points Achieved</b>		<b>Possible Points: 60</b>		
Certified 22 to 27 points   Silver 28 to 32 points   Gold 33 to 43 points   Platinum 44 or more points				
<b>8 Sustainable Sites</b> Possible Points: 15		<b>8 Materials &amp; Resources</b> Possible Points: 9		
Y		Y		
Y	Prereq 1 Erosion & Sedimentation Control	Y	Prereq 1 Storage & Collection of Recyclables	
1	Credit 1 Site Selection	1	Credit 1.1 Building Reuse, Maintain 75% of Existing Shell	
1	Credit 2 Development Density	1	Credit 1.2 Building Reuse, Maintain 95% of Existing Shell	
1	Credit 3 Brownfield Redevelopment	1	Credit 2.1 Construction Waste Management, Divert 50%	
1	Credit 4.1 Alternative Transportation, Public Transportation Access	1	Credit 2.2 Construction Waste Management, Divert 75%	
1	Credit 4.2 Alternative Transportation, Bicycle Storage & Changing Rooms	1	Credit 3.1 Resource Reuse, Specify 5%	
1	Credit 4.3 Alternative Transportation, Alternative Fuel Vehicles	1	Credit 4.1 Recycled Content, 5% (Post-consumer + 1/2 post-industrial)	
1	Credit 4.4 Alternative Transportation, Parking Capacity	1	Credit 4.2 Recycled Content, 10% (Post-consumer + 1/2 post-industrial)	
1	Credit 5.1 Reduced Site Disturbance, Protect or Restore Open Space	1	Credit 5.1 Local/Regional Materials, 20% Manufactured Locally	
1	Credit 5.2 Reduced Site Disturbance, Development Footprint	1	Credit 5.2 Local/Regional Materials, of 20% Above, 50% Harvested Locally	
1	Credit 6.1 Stormwater Management, Fate and Quantity	1	Credit 6 Rapidly Renewable Materials	
1	Credit 6.2 Stormwater Management, Treatment	1	1	Credit 7 Certified Wood
1	Credit 7.1 Heat Island Effect Non-Roof	1		
1	Credit 7.2 Heat Island Effect Roof	1		
1	Credit 8 Light Pollution Reduction	1		
1	Credit 9 Tenant Design and Construction Guidelines	1		
<b>3 Water Efficiency</b> Possible Points: 5		<b>9 Indoor Environmental Quality</b> Possible Points: 12		
Y		Y		
1	Credit 1.1 Water Efficient Landscaping, Reduce by 50%	Y	Prereq 1 Minimum IAQ Performance	
1	Credit 1.2 Water Efficient Landscaping, No Potable Use or No Irrigation	Y	Prereq 2 Environmental Tobacco Smoke (ETS) Control	
1	Credit 2 Innovative Wastewater Technologies	1	Credit 1 Carbon Dioxide (CO <sub>2</sub> ) Monitoring	
1	Credit 3.1 Water Use Reduction, 20% Reduction	1	Credit 2 Increase Ventilation Effectiveness	
1	Credit 3.2 Water Use Reduction, 30% Reduction	1	Credit 3 Construction IAQ Management Plan, During Construction	
		1	Credit 4.1 Low-Emitting Materials, Adhesives & Sealants   1 point for 2	
		1	Credit 4.2 Low-Emitting Materials, Paints   2 points for 3	
		1	Credit 4.3 Low-Emitting Materials, Carpet   3 points for 4	
		1	Credit 4.4 Low-Emitting Materials, Composite Wood	
		1	Credit 5 Indoor Chemical & Pollutant Source Control	
		1	Credit 6.1 Controllability of Systems, Perimeter	
		1	Credit 6.2 Controllability of Systems, Non-Perimeter	
		1	Credit 7.1 Thermal Comfort, Comply with ASHRAE 55-1992	
		1	Credit 7.2 Thermal Comfort, Permanent Monitoring System	
		1	Credit 8.1 Daylight & Views, Daylight 75% of Spaces	
		1	Credit 8.2 Daylight & Views, Views for 90% of Spaces	
<b>4 Energy &amp; Atmosphere</b> Possible Points: 14		<b>4 Innovation &amp; Design Process</b> Possible Points: 5		
Y		Y		
Y	Prereq 1 Fundamental Building Systems Commissioning	1	Credit 1.1 Innovation in Design:	
Y	Prereq 2 Minimum Energy Performance	1	Credit 1.2 Innovation in Design:	
Y	Prereq 3 CFC Reduction in HVAC&R Equipment	1	Credit 1.3 Innovation in Design:	
2	Credit 1 Optimize Energy Performance	1	Credit 1.4 Innovation in Design:	
1	Credit 2.1 Renewable Energy, 1%	1	Credit 2 LEED® Accredited Professional	
1	Credit 2.2 Renewable Energy, 5%			
1	Credit 3 Additional Commissioning			
1	Credit 4 Ozone Depletion			
1	Credit 5 Measurement & Verification			
1	Credit 6 Green Power			

Fig. 64: LEED-CS Pilot Scorecard



LEED-CI

ACIN @ NJEDA's Waterfront Technology Center at Camden

LEED-CI® v2.0 Project #10002906

LEED-CI Certification Level: GOLD

17 October 2006

33 Points Achieved		Possible Points: 57	
Certified 21 to 28 points Silver 27 to 31 points Gold 32 to 41 points Platinum 42 or more points			
<b>6 Sustainable Sites</b>		<b>10 Indoor Environmental Quality</b>	
Possible Points: 7		Possible Points: 17	
Y		Y	
3	Credit 1 Site Selection	3	Y Prereq 1 Minimum IAQ Performance
1	Credit 2 Development Density and Community Connectivity	1	Y Prereq 2 Environmental Tobacco Smoke (ETS) Control
1	Credit 3.1 Alternative Transportation, Public Transportation Access	1	1 Credit 1 Outdoor Air Delivery Monitoring
	Credit 3.2 Alternative Transportation, Bicycle Storage & Changing Rooms	1	1 Credit 2 Increased Ventilation
1	Credit 3.3 Alternative Transportation, Parking Availability	1	1 Credit 3.1 Construction IAQ Management Plan, During Construction
			1 Credit 3.2 Construction IAQ Management Plan, Before Occupancy
<b>2 Water Efficiency</b>		<b>3 Innovation &amp; Design Process</b>	
Possible Points: 2		Possible Points: 5	
Y		Y	
1	Credit 1.1 Water Use Reduction, 20% Reduction	1	1 Credit 1.1 Innovation in Design: Exemplary Performance, MRc3.3
1	Credit 1.2 Water Use Reduction, 30% Reduction	1	1 Credit 1.2 Innovation in Design: Exemplary Performance, MRc5.1
<b>5 Energy &amp; Atmosphere</b>		Possible Points: 14	
Possible Points: 12			
Y			
Y	Prereq 1 Fundamental Commissioning		
Y	Prereq 2 Minimum Energy Performance		
Y	Prereq 3 CFC Reduction in HVAC&R Equipment		
2	Credit 1.1 Optimize Energy Performance, Lighting Power		
	Credit 1.2 Optimize Energy Performance, Lighting Controls		
1	Credit 1.3 Optimize Energy Performance, HVAC		
	Credit 1.4 Optimize Energy Performance, Equipment & Appliances		
	Credit 2 Enhanced Commissioning		
2	Credit 3 Energy Use, Measurement & Payment Accountability		
	Credit 4 Green Power		
<b>7 Materials &amp; Resources</b>		Possible Points: 5	
Possible Points: 14			
Y			
Y	Prereq 1 Storage & Collection of Recyclables		
1	Credit 1.1 Tenant Space, Long Term Commitment		
	Credit 1.2 Building Reuse, Maintain 40% of Interior Non-Structural Components		
	Credit 1.3 Building Reuse, Maintain 60% of Interior Non-Structural Components		
1	Credit 2.1 Construction Waste Management, Divert 50% From Landfill		
1	Credit 2.2 Construction Waste Management, Divert 75% From Landfill		
	Credit 3.1 Resource Reuse, 5%		
	Credit 3.2 Resource Reuse, 10%		
1	Credit 3.3 Resource Reuse, 30% Furniture and Furnishings		
1	Credit 4.1 Recycled Content, 10% (Post-consumer + 1/2 pre-consumer)		
1	Credit 4.2 Recycled Content, 20% (Post-consumer + 1/2 pre-consumer)		
1	Credit 5.1 Regional Materials, 20% Manufactured Regionally		
	Credit 5.2 Regional Materials, 10% Extracted and Manufactured Regionally		
	Credit 6 Rapidly Renewable Materials		
	Credit 7 Certified Wood		

Fig. 65: LEED-CI v2.0 Scorecard: ACIN







LEED for Commercial Interiors v2.0

NJEDA @ Waterfront Technology Center  
 Project #: 10077849  
 Certification Level: XXXX  
 CERTIFICATION DATE

35 Points Achieved		Possible Points: 57		
Certified 21 to 26 points Silver 27 to 31 points Gold 32 to 41 points Platinum 42 or more points				
<b>6 Sustainable Sites</b> Possible Points: 7		<b>10 Indoor Environmental Quality</b> Possible Points: 17		
Y		Y		
3	Credit 1 Site Selection	3	Y Prereq 1 Minimum IAQ Performance	
1	Credit 2 Development Density and Community Connectivity	1	Y Prereq 2 Environmental Tobacco Smoke (ETS) Control	
1	Credit 3.1 Alternative Transportation, Public Transportation Access	1	1 Credit 1 Outdoor Air Delivery Monitoring 1	
	Credit 3.2 Alternative Transportation, Bicycle Storage & Changing Rooms	1	Credit 2 Increased Ventilation 1	
1	Credit 3.3 Alternative Transportation, Parking Availability	1	1 Credit 3.1 Construction IAQ Management Plan, During Construction 1	
			Credit 3.2 Construction IAQ Management Plan, Before Occupancy 1	
<b>2 Water Efficiency</b> Possible Points: 2			1 Credit 4.1 Low-Emitting Materials, Adhesives & Sealants 1	
Y		1	1 Credit 4.2 Low-Emitting Materials, Paints and Coatings 1	
1	Credit 1.1 Water Use Reduction, 20% Reduction	1	1 Credit 4.3 Low-Emitting Materials, Carpet Systems 1	
1	Credit 1.2 Water Use Reduction, 30% Reduction	1	1 Credit 4.4 Low-Emitting Materials, Composite Wood and Laminate Adhesives 1	
<b>4 Energy &amp; Atmosphere</b> Possible Points: 12			Credit 4.5 Low-Emitting Materials, Systems Furniture and Seating 1	
Y		1	1 Credit 5 Indoor Chemical & Pollutant Source Control 1	
Y	Prereq 1 Fundamental Commissioning		Credit 6.1 Controllability of Systems, Lighting 1	
Y	Prereq 2 Minimum Energy Performance		Credit 6.2 Controllability of Systems, Temperature and Ventilation 1	
Y	Prereq 3 CFC Reduction in HVAC&R Equipment		1 Credit 7.1 Thermal Comfort, Compliance 1	
1	Credit 1.1 Optimize Energy Performance, Lighting Power	3	1 Credit 7.2 Thermal Comfort, Monitoring 1	
	Credit 1.2 Optimize Energy Performance, Lighting Controls	1	1 Credit 8.1 Daylight & Views, Daylight 75% of Spaces 1	
1	Credit 1.3 Optimize Energy Performance, HVAC	2	Credit 8.2 Daylight & Views, Daylight 90% of Spaces 1	
	Credit 1.4 Optimize Energy Performance, Equipment & Appliances	2	Credit 8.3 Daylight & Views, Views for 90% of Seated Spaces 1	
	Credit 2 Enhanced Commissioning	1	<b>5 Innovation &amp; Design Process</b> Possible Points: 5	
2	Credit 3 Energy Use, Measurement & Payment Accountability	2	Y	
	Credit 4 Green Power	1	1	1 Credit 1.1 Innovation in Design: Exemplary Performance in MRc4 1
<b>8 Materials &amp; Resources</b> Possible Points: 14			1	1 Credit 1.2 Innovation in Design: Exemplary Performance for MRc5.1 1
Y			1	1 Credit 1.3 Innovation in Design: Exemplary Performance for MRc3.3 1
Y	Prereq 1 Storage & Collection of Recyclables		1	1 Credit 1.4 Innovation in Design: LEED-CI Idc1.1 CIR 1
1	Credit 1.1 Tenant Space, Long Term Commitment	1	1	1 Credit 2 LEED® Accredited Professional 1
	Credit 1.2 Building Reuse, Maintain 40% of Interior Non-Structural Components	1		
	Credit 1.3 Building Reuse, Maintain 80% of Interior Non-Structural Components	1		
1	Credit 2.1 Construction Waste Management, Divert 50% From Landfill	1		
1	Credit 2.2 Construction Waste Management, Divert 75% From Landfill	1		
	Credit 3.1 Resource Reuse, 5%	1		
	Credit 3.2 Resource Reuse, 10%	1		
1	Credit 3.3 Resource Reuse, 30% Furniture and Furnishings	1		
1	Credit 4.1 Recycled Content, 10% (Post-consumer + 1/2 pre-consumer)	1		
1	Credit 4.2 Recycled Content, 20% (Post-consumer + 1/2 pre-consumer)	1		
1	Credit 5.1 Regional Materials, 20% Manufactured Regionally	1		
1	Credit 5.2 Regional Materials, 10% Extracted and Manufactured Regionally	1		
	Credit 6 Rapidly Renewable Materials	1		
	Credit 7 Certified Wood	1		

Fig. 67: LEED-CI v2.0 Scorecard: NJEDA



## About the Rutgers Center for Green Building

**The Rutgers Center for Green Building (RCGB)** is located at the Edward J. Bloustein School of Planning and Public Policy, Rutgers, The State University of New Jersey. The Center works with industry and government to promote green building best practices, and develops undergraduate, graduate and professional education programs. The Center is quickly establishing itself as the pre-eminent interdisciplinary center for green building excellence in the Northeast, while serving as a single accessible locus for fostering collaboration among green building practitioners and policymakers.

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