Controlling Capital Costs in High-Performance Office Buildings

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http://www1.eere.energy.gov/buildings/alliances/media/20111031_webinar_controlling_costs.wmv

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.
Webinar Review

Maximum Efficiency with Deep Integration

• Cost and energy efficiency concepts
• Introduction to a high-performance office building
• Best practices for controlling capital costs
  o Acquisition and project delivery
  o Design
  o Construction
• Questions
Cost vs. Efficiency?
Research Support Facility Vision

- A showcase for sustainable, high-performance design
  - Incorporates the best in energy efficiency, environmental performance, and advanced controls using a “whole-building” integrated design process
- Serves as a model for cost-competitive, high-performance commercial buildings for the nation’s design construction, operation, and financing communities
Research Support Facility

- 824 people
- 220,000 ft²
- 25 kBtu/ft²
- 50% energy savings
- $259/ft²
- LEED® Platinum
- Replicable
  - Process
  - Technologies
  - Cost
- Site, source, carbon, cost net zero energy building
  - Includes plugs loads and data center
- Design/build process with required energy goals
  - $64 million firm fixed price
• First, focus on **energy efficiency features**.

• Then, focus on adding **renewable energy** into the equation.

• Unlike traditional design where architecture defines the form and impacts the function of a building, **energy performance requirements** drove the design of the RSF.

• **Extensive energy modeling** established the basic building architecture and structure.
Key Design Strategies

- Optimal orientation and office space layout
- Fully daylit office wings with high-performance electrical lighting
- Continuous insulation and precast wall panels with thermal mass
- Operable windows for natural ventilation
- Radiant heating and cooling
- Outdoor air preheating
  - Transpired solar collector
  - Data center waste heat
  - Exhaust air heat recovery
  - Crawl space thermal storage
- Aggressive plug load control strategies
- Data center outdoor air economizer with hot aisle containment
- Roof top- and parking lot-based PV
Owner Best Practices

#1. Select a project delivery method that balances performance, best value, and cost savings.

- Encourages innovation
- Reduces owner’s risk
- Faster construction and delivery
- Better cost control
- Makes optimal use of team members’ expertise
- Establishes measurable success criteria
#2. Incorporate measurable energy use performance requirements into a performance-based design-build procurement process.

• Measurable goals are better
• From bad to good...
  o I want a green building
  o Design a LEED <rating> building
  o Design a building to use 30% less energy than ASHRAE 90.1-2004
  o Design a building to use less than 25,000 Btu/ft²
  o Design a [NET] ZERO ENERGY BUILDING

• Influencing purchasing decision—the owner
Energy Performance Based Design-Build Process

• Performance based design-build with absolute energy use requirements
  o These are NOT bridging documents.
    – Owner has significant input into the preliminary design
    – Some overlap of A/E costs
  o These ARE performance specifications.
    – What something must do, not what it must be
    – Subcontractor must substantiate that the design meets requirements
    – Owner must not give the subcontractor technical direction

No drawings/plans in RFP!

Don’t change your mind
#3. Clearly prioritize project objectives at the beginning of the design process.

- Use of a project objectives checklist to prioritize project goals in the RFP
  - Mission critical
  - Highly desirable
  - If possible

- “Crystal clear” about what the owner wants at the beginning of design
  - Saves time trying to “understand” owner wants
Developing a Performance Based Request for Proposals

• Up-front planning drives success
  o Design charrettes
  o Based on industry best practices
  o Owner’s representatives

• Design challenge
  o Suite of performance goals to challenge team
  o Substantiation criteria

### Tier 1: Mission Critical Goals
- Attain safe work/design
- LEED Platinum
- ENERGY STAR® “Plus”

### Tier 2: Highly Desirable Goals
- 800 staff capacity
- 25 kBtu/ft²-yr
- Architectural integrity
- Honor future staff needs
- Measurable ASHRAE 90.1
- Support culture and amenities
- Expandable building
- Ergonomics
- Flexible workspace
- Support future technologies
- Documentation to produce “how to” manual
- Allow secure collaboration with visitors
- Completion by 2010

### Tier 3: If Possible Goals
- Net-zero energy
- Most energy-efficient building in the world
- LEED Platinum Plus
- 50% better than ASHRAE 90.1
- Visual displays of current energy efficiency
- Support public tours
- Achieve national and global recognition and awards
#4. Competitively procure an experienced design-build team using a best value, firm fixed price process.

- $64M project cost limit
- Every project always has more scope than funding
- Design-build team selection based on competitions focused on amount of scope that can be provided for the money available

- Results in industry design, integration, and teaming innovation
#5. Include best in class energy efficiency requirements in equipment procurement specifications.

- Laptops and monitors
- Multifunction devices
- Data center servers
- 6-Watt LED task lights
- Break room refrigerators
- 55” LED LCD flat screen

- ENERGY STAR® product database and “Best in Class” program
Energy-Efficient Workspace

- **24” LCD energy-efficient monitors**
  - 18 Watts

- **Typical 19”-24” monitors**
  - 30-50 Watts

- **Laptop**
  - 30 Watts

- **Desktop computer (ENERGY STAR®)**
  - 300 Watts

- **LED task lights**
  - 6 Watts

- **Fluorescent task lights**
  - 35 Watts

- **Multi-function devices**
  - 100 Watts (continuous)

- **VOIP phones**
  - 2 Watts

- **Power strip on the desktop**
  - Easy to access power button

- **Removing personal space heater**
  - Saves 1500 Watts

- **Workstation load**
  - 55 Watts

- **0.4 W/ft² whole-building plug load intensity**

- **Removing desktop printers**
  - Saves ~460 Watts/printer
Design Best Practices

#6. Leverage value added benefits to efficiency strategies.

- Machine-room-less traction elevators
  - Requires less building footprint support structure than hydraulics
- Laptops for all staff
  - Increases mobility and workspace flexibility
- Centralized copy/print functions with multifunction device
  - Exhaust volatile organic compounds (VOCs) from toners
  - Minimize unique toner replacement stock
- Views and daylighting for all with demountable open office plan
  - Increase space reconfiguration flexibility
  - Give all staff views
Daylighting

• Light enters through the upper glass and highly reflective louvers direct it toward the ceiling and deeper into the space.

• Light-colored, reflective surfaces and low cubicle heights permit the penetration deep into workspaces.
#7. Consider life cycle costs benefits of efficiency investments.

RSF Optimization Run

- Reduction of Capital Costs: Reduced WWR
- Decreased Aspect Ratio
- 50% Reduction in Lighting
- Increased Insulation and Window Performance
- 50% Reduction in Plug Loads
- Natural Ventilation
- Increased Aspect Ratio
- Daylighting Control

Credit: Shanti Pless and Chad Lobato, NREL
Design Best Practices

#8. Integrate simple and passive efficiency strategies with the architecture and envelope.

- Reduce loads first
  - Insulation and thermal bridging mitigation
  - Effective shading
  - Orientation and window placement
- Then focus on passive systems
  - Simpler and more robust envelope solutions
  - Minimize moving parts
Efficiency Integrated into Architecture

- Daylighting
- Thermal mass
- Natural ventilation
- Shading
- Orientation
- Massing and form
- Thermally activated building structure
- Transpired solar collector
Daylighting
• Two long 60-foot wide wings with east-west orientation
• Design reduces electrical lighting
Daylighting: Glare Control

A light-redirecting device reflects sunlight to the ceiling, creating an indirect lighting effect.

Fixed sunshades limit excess light and glare.

Credit: RNL
Building Structural Elements and Efficiency

Labyrinth Thermal Storage

- Massive, staggered concrete structures in the basement crawl space stores thermal energy to provide passive heating and cooling of the building.

Credit: RNL
Design Best Practices

#9. Allow for cost tradeoffs across disciplines.

Transfer costs from mechanical and electrical systems to building architecture.

- Total cost same
- Mechanical/electrical costs less
- Invest in architecture, design, and modeling
- Active to passive
- Fragile to robust
- Longer life
- Less cost over life
- Simpler

Credit: RNL
Design Best Practices

#10. Optimize window area for daylighting and views.

Optimal window area strategy that balances cost, thermal performance, daylighting, and views.

- 24%-26% window-to-wall ratio
- 11% window-to-wall ratio for daylighting windows
Design Best Practices

#11. Maximize use of modular and repeatable high-efficiency design strategies.

Focus on repeatable design elements.

- Minimize unique and expensive building elements
- No curved walls
- Punched windows
- Increase space efficiency
Modular Design: Kit of Parts

Credit: RNL
Modular Floor Plans

267 ft\(^2\) per occupant workstation

Credit: RNL
Modular Office Space

- Maximizes space efficiency
  - Allows for 72 ft$^2$ and 120 ft$^2$ office cubicles
- Reduces drywall costs
- Building designed around 30 ft x 60 ft office space modules
Design Best Practices

#12. Leverage alternative financing to incorporate strategies that don’t fit your business model.

- Power purchase agreements
- Energy services contracts
- Utility rebate programs
Photovoltaic System

- Power Purchase Agreement (PPA) provides full rooftop array on RSF 1
- Net-zero energy: building, parking lot and future parking garage arrays
Construction Best Practices

#13. Maximize use of off-site modular construction and building component assembly.

• Off-site assembly reduces on-site construction time
  • Faster site assembly
• Increases quality and reduces costs
• Minimizes site coordination details and safety concerns
 Precast Wall System
• Incorporates many passive heating and cooling techniques.
• Six inches of concrete on the interior provides thermal mass that helps moderate internal temperatures year-round.
• Nighttime purges in summer months trap cool air inside, keeping temperatures comfortable for the warm summer days.
Off-Site Glazed Wall Panels
• **42 miles** of radiant heating tubes run through the ceilings throughout the building.
Radiant Heating/Cooling

- Office wings are hydronically heated and cooled using radiant ceiling slabs.

- Five zones in each wing of the building are controlled by the radiant zone control valves.
Construction Best Practices

#14. Include a continuous value engineering process as part of the integrated design effort.

- A well-integrated design-build team can identify value additions during the design process.
- Balance cost models with energy models in early design.
A Value Addition Process

View looking East into the Entry Plaza
Constructing Zero Energy

Integrated Design and Construction

5-Sided Problem Solving

- Cost and Budget Models
- Energy Models
- Thermal Comfort Models
- Daylight Models
- Architecture and Program Models

Credit: Haselden
Construction Best Practices

#15. Integrate experienced key subcontractors early in the design process.

The big 5 subcontractors – select early for cost control and constructability verification

- Structural steel
- Mechanical/plumbing – AHU’s, hydronic, pumps
- Electrical – lighting, cabling, electrical distribution
- **Envelope** – the single most costly per SF and the most impactful to energy
  - Glass and glazing
  - Precast concrete wall system
Metrics of Success…

- Received elements/value that were not in the RFP (or did not help the energy efficiency)
  - Fancy woodwork detail
  - Extra glazing
- Comparison with other costs
Reclaimed natural gas piping serves as support for the building. The lobby and other common areas feature beetle-kill pine from Western forests.

LEED Platinum rating, version 2.2 – 59 points.
How Much Did It Cost?

• $259/ft² construction costs for site work, infrastructure, and building
  o Includes interiors, furniture, and cabling
  o Does not include PV, land, or design costs

• Third-party-owned power purchase agreement for PV
  o $29/ft² or 11% additional cost if NREL had purchased all PV without tax breaks or subsidies (at $5/Watt)
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Data used by permission from the Design-Build project database hosted by DBIA at www.dbia.org
RSF and Cost Concepts

The RSF will meet or exceed all the project objectives at our budget at a firm fixed price.

- So what is the payback?

The RSF construction costs are similar to other institutional office buildings.
Replicable – Cost Control Review

- Firm fixed price with required energy goals in design-build contract
- Integrated architecture and envelope as efficiency measures
- Simple and commercially viable
- No unique technologies required
- Modular precast wall panels with minimal finishes
- Optimized glazing area
- Repeatable office floorplate
- Takes a coordinated effort with the owner (and all user groups), architect, builder, and engineers
Replicable – Owner Review

• Owner made tough decisions up front
  o Set budget
  o Sought maximum value for that budget
  o Prioritized goals

• Design-build procurement process
  o Managed the team to the RFP and its substantiation criteria
  o Rewards

• Allowed design-build team to use creativity to maximize value (innovation)

• Owner did not solve the problem (but knew the solution existed)
Questions

Thanks for your time and attention

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