Zero net energy building cost and feasibility
MAY 26

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Speakers

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Senior Energy Efficiency Research Engineer, NREL

Scott Hackel
Principal Energy Engineer, Seventhwave
“Wood, our common fuel, which within these hundred years might be had at every man’s door, must now be fetched near one hundred miles to some towns, and makes a very considerable article in the expense of families.” (1744)
Market Drivers

- California PUC 2030
- Massachusetts 2030
- Federal / EISA 2030
- Public Relations/Marketing
- ASHRAE Vision 2020
- 2030 Challenge
- Living Building Challenge
- Energy cost uncertainty
**Zero Energy Mandate for Federal Buildings**

- **2020:** Zero energy design for new buildings
- **2025:** 1% of existing buildings will achieve zero energy, waste, or water.
- **2030:** Zero water or waste design for new buildings.

Executive Order 13693

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**Zero Energy Building Definition**

- **Renewable Energy Exported from Site ≥ Energy Delivered to Site**
- Must make adjustments for source energy
- Electric vehicle charging is counted as exported energy
- Site boundaries: Building, Campus, Portfolio, or Community
- “Renewable Energy Certificate Zero Energy Building” definition for buildings that use purchased off-site renewable energy

DOE/EE-1247 A Common Definition for Zero Energy Buildings
Scale

Building?

Campus?

District or community?

Beyond?

2030district.org/
Simple Photovoltaic Budget

Energy (kWh/year) = Panel Area (ft²) x Solar Radiation (kWh/m²∙d) x Efficiency (%) x 33.9 (day∙ft²/year∙m²)

PV Source Energy = PV Energy x 3.15

NREL Photovoltaic Modeling Tools

PVWatts
- Automates solar radiation lookup
- Guidance for efficiency and losses

System Advisor Model (SAM)
- Includes cost and financial information
- Advanced modeling capabilities

pvwatts.nrel.gov/ sam.nrel.gov/
Redesigning Roofs for PV Systems

- Relocate HVAC systems
- Roof design can reduce PV cost
- Installation best practices

Solar Ready Buildings Planning Guide
http://www.nrel.gov/docs/fy10osti/46078.pdf
Focus on Efficiency

✓ Performance requirements drive design. Form follows performance.

✓ First, focus on **load reduction** and then, **energy efficiency** features.

✓ Then, adding **renewable energy** into the equation.

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Energy Performance Example

![Energy Performance Example Chart]

Annual Energy Use Intensity Comparison

*Credit: Chad Lobato/NREL*
Benchmark for Context

Benchmarking Resources

- DOE Commercial Reference Buildings
  - Simulation data available (no modeling required)
  - Can download EnergyPlus models and edit

- CBECs

- NBI Zero Energy Database

- Building disclosure data sets
Energy Usage Target

Source energy adjustments:
- Separate for electric and natural gas
- (EUI is not enough information)

Source Energy (kBtu/year) =
3.15 x Electric Energy (kBtu/year) + 1.09 x Natural Gas Energy (kBtu/year)

Reductions of 50-75% are common in zero energy buildings.

Putting the pieces together
Conceptual Energy Modeling

Energy Model SKETCH

Energy benchmarking and analysis
Community engagement
Measurement and verification
Facilitate internal needs
Plug load (equipment) advocate
Education and training
Architectural programming
Contracts
Operations and maintenance

Post Design / Construction
Influence of people, post-design

Post-design measures

- Occupant behavior, 8.5
- Operations, 14
- Execution: construction and Oc, 13.5
- Design, 12
- Unregulated components, 18.5
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Research Support Facility at NREL 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
How-to Guides for Cost Control

Guide:
- Discusses the recommended strategies
- Pairs strategies with industry examples of success in ZEBs and other high-performance buildings where possible
- Describes how to balance key decision-making factors
- Provides quick reference tables to help building owners and project teams apply the recommended strategies to their projects.

Fact sheet:
- [https://buildingdata.energy.gov/cbrd/resource/1654](https://buildingdata.energy.gov/cbrd/resource/1654)
- Highlights key ideas from the guide
- Directs readers to the guide for more details.

How to Use the Guide

A holistic, comprehensive approach is most effective.
- Take advantage of as many strategies as possible to maximize benefits.
- Strategies used in early phases set the stage for opportunities later in the process.
- For best results, adopt the full set of strategies.

- **Strategies are labeled by primary audience:**
  - Owners and developers
  - Architects and design engineers
  - Contractors and subcontractors
Overarching Principles

- Select a delivery method that elevates the importance of energy performance to be on par with other project objectives.
  - Energy efficiency requirements in a competitive delivery process promote the innovation needed for high performance on a budget.

- Emphasize integrated design and team communication.
  - Integrated design results in lower construction costs and better performance.
  - Team decision-making limits misunderstandings and ensures effective use of individual expertise.

- Leverage energy modeling early and often.
  - Ensure that project decisions contribute to the achievement of energy performance goals.

Acquisition and Delivery Best Practices

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

- Incorporate measurable energy use performance requirements into a performance-based design-build procurement process.

- Clearly prioritize project objectives at the beginning of the design process.

- Competitively procure an experienced design-build team using a best value, firm fixed price process.

- Include best in class energy efficiency requirements in equipment procurement specifications
Design Best Practices

✓ Leverage value added benefits to efficiency strategies.
✓ Consider life cycle costs benefits of efficiency investments.
✓ Integrate simple and passive efficiency strategies with the architecture and envelope.
✓ Allow for cost tradeoffs across disciplines.
✓ Optimize window area for daylighting and views.
✓ Maximize use of modular and repeatable high-efficiency design strategies.
✓ Leverage alternative financing to incorporate strategies that don’t fit your business model.

Construction Best Practices

✓ Maximize use of off-site modular construction and building component assembly.
✓ Include a continuous value engineering process as part of the integrated design effort.
✓ Integrate experienced key subcontractors early in the design process
NREL Campus Growth with Design-Build

- Procurement process attributes pre-2007:
  - Design-bid-build project delivery
  - LEED-driven sustainability goals

- Procurement process attributes post-2007:
  - Design-build project delivery with firm fixed price for >$400 Million of new facilities
  - Specific energy performance requirements in the Request for Proposal
    - RSF, office example: 35 kBtu/ft²/yr
    - SEB, guard house example: net zero energy
  - Energy modeling required to substantiate goals
  - Energy end-use metering requirement
  - Voluntary incentive ($) program to ensure measurement and verification outcome has a chance to meet predicted performance

CONTRACTS DRIVE BEHAVIOR
Developing a Performance Based Request for Proposals

- Up-front planning drives success
- Design charrettes
- Based on industry best practices
- Owner’s representatives
- Design challenge
- Suite of performance goals to challenge team
- Substantiation criteria

Owner Best Practices

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
Design Best Practices

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

Design Best Practices

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
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

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

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

ENVELOPE

Energy driven form 115,000 SF
Conventional form 65,000 SF
Design Best Practices

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 Office Space

- Maximizes space efficiency
  Allows for 72 ft² and 120 ft² office cubicles
- Reduces drywall costs
- Building designed around 30 ft x 60 ft office space modules
Design Best Practices

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
- Zero energy = building, parking lot and future parking garage arrays
Photovoltaics – Design and Install Cost Savings

- PV contractor involved with installation
- Installation technique improvements
- Standing Seam Roof

Construction Best Practices

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

75 miles of radiant heating tubes run through the ceilings throughout the building.
Construction Innovation

- 5 days per deck allowed
  - 2 days per deck
  - 85% faster
- Offsite pre-fab of zones

Construction Best Practices

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.

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**How Much Did It Cost?**

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

- $246/ft² construction cost for third wing

- Third-party-owned power purchase agreement for PV
  - $29/ft² or 11% additional cost if NREL had purchased all PV without tax breaks or subsidies (at $5/Watt)
**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
# Performance-based procurement

![Diagram of performance-based procurement process]

## RFP and contract language: tiered goals

**PROJECT GOAL LIST:** Project goals help design teams prioritize their focus on the MEP and building performance design. Goals are categorized in three main sections:

- **Mission critical goals** - required by contract and critical to success
- **Highly desirable goals** - not required by contract and have influence on the recommended design
- **If possible goals** - influence recommended design and are considered highly beneficial if included in the solution

### MISSION CRITICAL
- Maximum energy target of 45 KBTU/gsf annually; lower is preferred
- LEED NC version 4, Silver Certification
- Superior occupant comfort
- 100% of occupied spaces physically or visually connected to nature
- Living Building Challenge (LBC) 3.0 Feasibility Study

### HIGHLY DESIRABLE
- Maximum energy target of 35 kBtu/gsf annually; lower is preferred
- Best in class Energy Star equipment or best in class energy efficient equipment
- Passive design strategies (i.e. daylighting, passive solar heating, etc.)
- Achieve "retreat-like" feel using biophilic design principles
- Low recycled air content
- Strong HVAC response to quickly changing occupancy (limit precooling with air)
- Usable daylight in all occupied spaces
- Geothermal system
- Design features that create an interactive sustainable learning experience
- Exceed LEED NC version 4, Silver Certification

### IF POSSIBLE
- Living Building full certification
- Net Zero Energy Design
Other Financial Support

- Federal tax benefits
- Utility efficiency and renewable incentive programs
- ICECF

http://www.illinoiscleanenergy.org

New Construction Service—What We Do

- Provide expert technical assistance
- Deliver high-quality education and training
- Offer financial incentives for implementation
**New Construction Service Eligibility**

Can support building design projects if they are:

- In ComEd service territory
- A new construction or major renovation
- Privately owned or non-profit
- Minimum 5,000 square feet
- Exceed current Illinois energy code requirements (*IECC 2015*)
- Early in design!!

**Incentives Linked to Engagement**

Increasing levels based on earlier engagement in technical assistance

- Up to $0.14/kWh max. for projects engaging before hiring design team and implementing energy goals.
- Up to $0.10/kWh max. for projects engaging between the beginning of schematic design phase and 50% design development.
- Up to $0.07/kWh max. for projects engaging after 50% design development but before bidding.
- $0.00/kWh once project/equipment out to bid.
Contact

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