NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Controlling Capital Costs in High-Performance Office Buildings

Shanti Pless, LEED AP
Senior Research Engineer
NREL Advanced Commercial Buildings Research Group

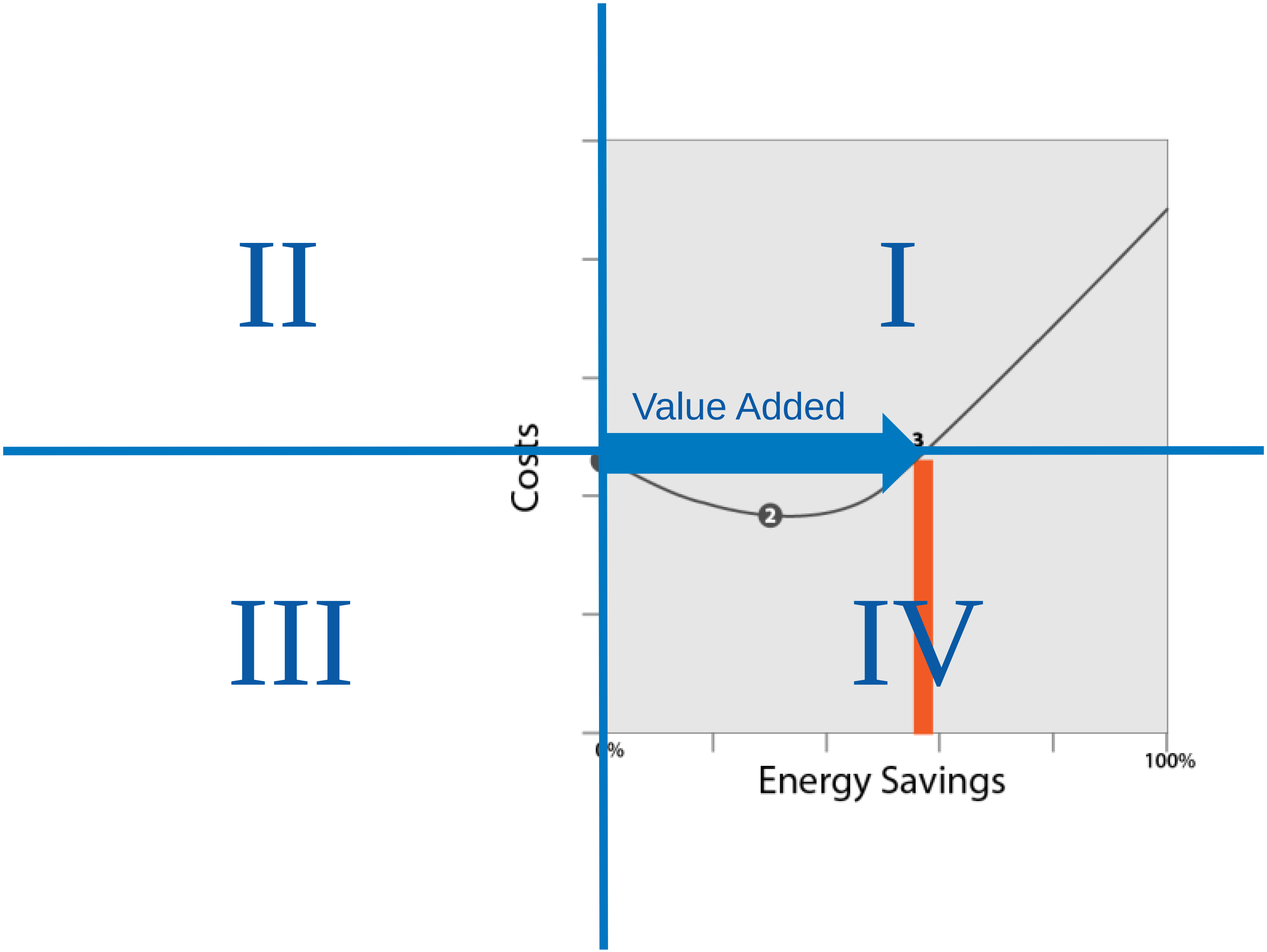
Paul Torcellini, PhD, PE
DOE Commercial Buildings Team

Webinar Review

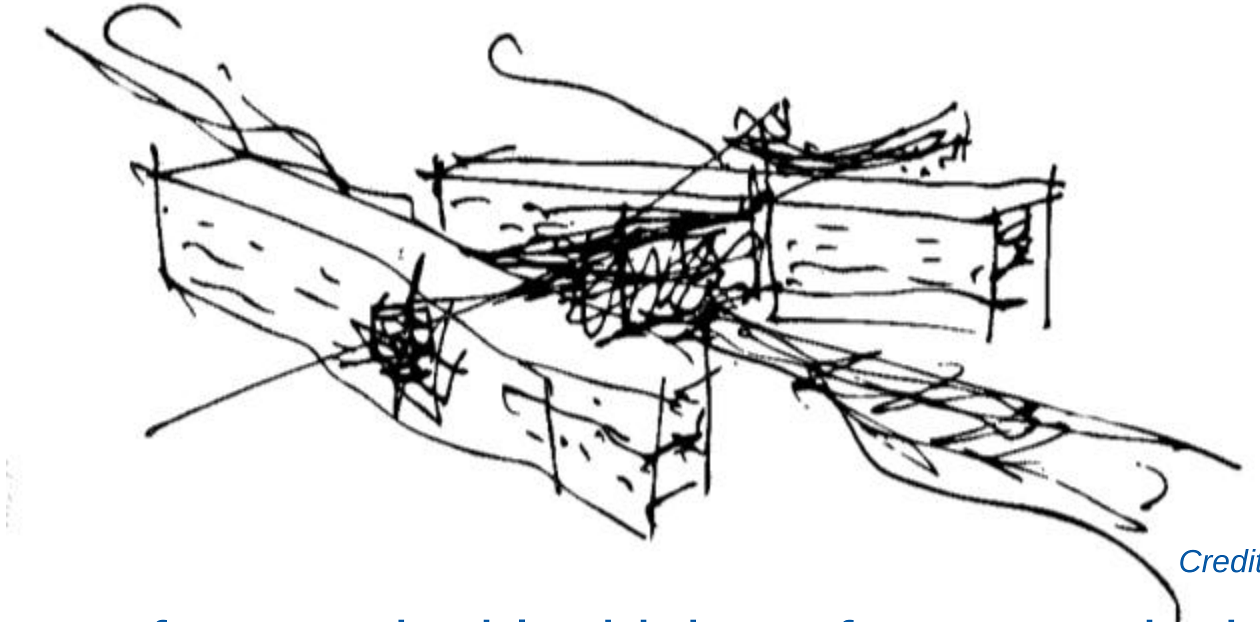
Maximum Efficiency with Deep Integration

- Cost and energy efficiency concepts
- Introduction to a high-performance office building
- Best practices for controlling capital costs
  - Acquisition and project delivery
  - Design
  - Construction
- Questions

Cost vs. Efficiency?



Research Support Facility Vision



Credit: RNL

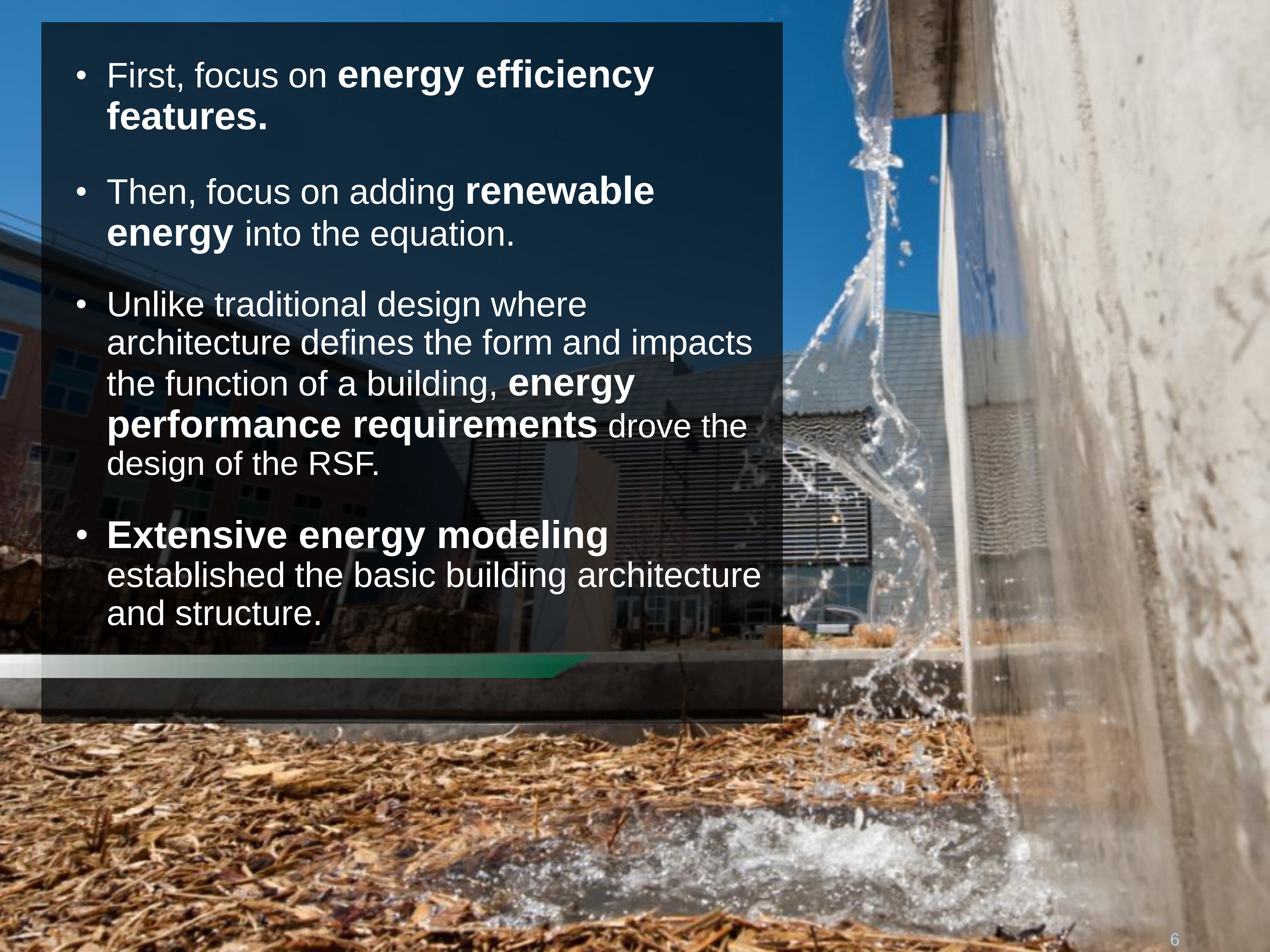
- A showcase for sustainable, high-performance design
  - Incorporates the best in energy efficiency, environmental performance, and advanced controls using a “whole-building” integrated design process
- Serves as a model for cost-competitive, high-performance commercial buildings for the nation’s design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

Research Support Facility

- 824 people
- 220,000 ft^2
- 25 $kBtu/ft^2$
- 50% energy savings
- $\$259/ft^2$
- LEED® Platinum
- Replicable
  - Process
  - Technologies
  - Cost

Credit: RNL

- 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.

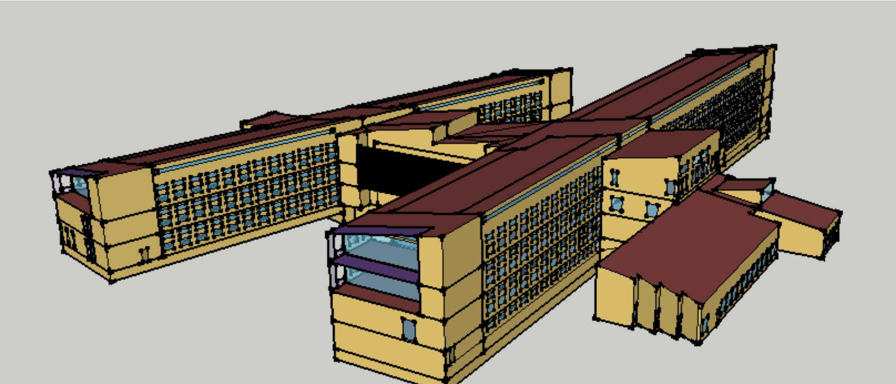
Key Design Strategies

- 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



Credit: AEC

Owner Best Practices

#2. Incorporate measureable energy use performance requirements into a performance-based design-build procurement process.

- Measurable goals are better
- From bad to good…
    - I want a green building
    - Design a LEED <rating> building
    - Design a building to use 30% less energy than ASHRAE 90.1-2004
    - Design a building to use less than 25,000 Btu/ft^2
    - 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
  - These are NOT bridging documents.
    - Owner has significant input into the preliminary design
    - Some overlap of A/E costs
  - 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

Owner Best Practices

#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
  - Design charrettes
  - Based on industry best practices
  - Owner's representatives
- Design challenge
  - Suite of performance goals to challenge team
  - 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/ft^2·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

Owner Best Practices

#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

Owner Best Practices

#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

Workstation load: 55 Watts
0.4 W/ft^2 whole-building plug load intensity

Power strip on the desktop

Easy to access power button

VOIP phones: 2 Watts

Removing personal space heater saves 1500 Watts

LED task lights
6 Watts

Fluorescent task lights 35 Watts

24" LCD energy-efficient monitors
18 Watts

Typical 19"-24" monitors
30-50 Watts

Laptop
30 Watts

Desktop computer (ENERGY STAR®)
300 Watts

Multi-function devices
100 Watts (continuous)

Removing desktop printers saves ~460 Watts/printer

Design Best Practices

#6. Leverage value added benefits to efficiency strategies.

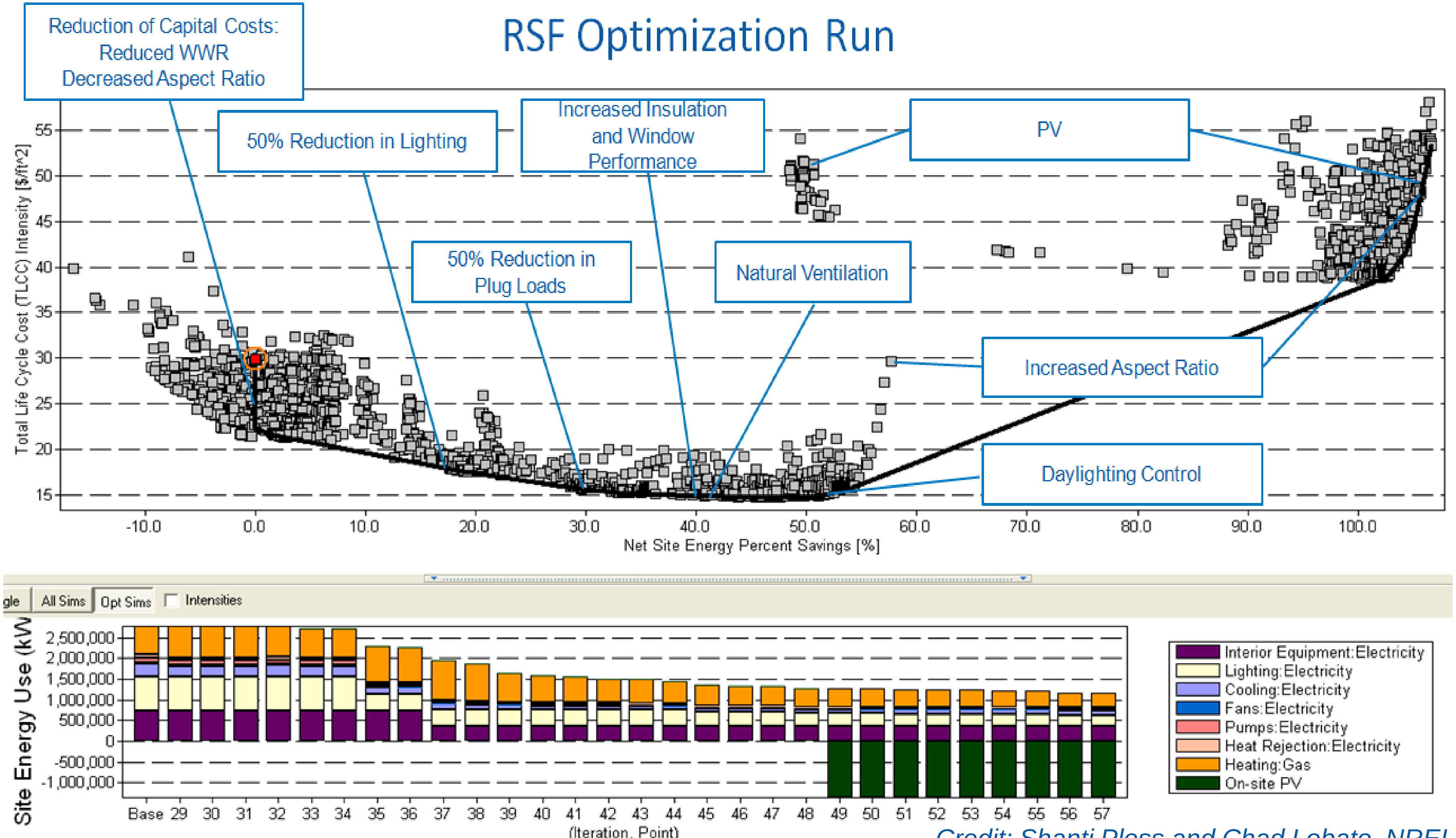
- Machine-room-less traction elevators
  - Requires less building footprint support structure than hydraulics
- Laptops for all staff
  - Increases mobility and workspace flexibility
- Centralized copy/print functions with multifunction device
  - Exhaust volatile organic compounds (VOCs) from toners
  - 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.

Design Best Practices

#7. Consider life cycle costs benefits of efficiency investments.



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

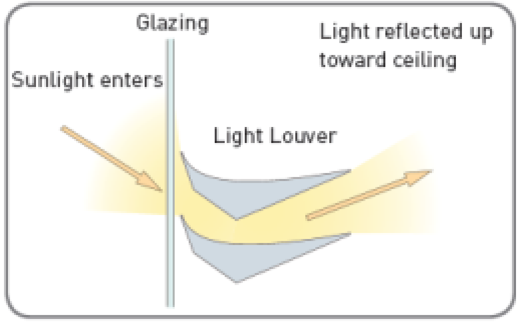
Daylighting

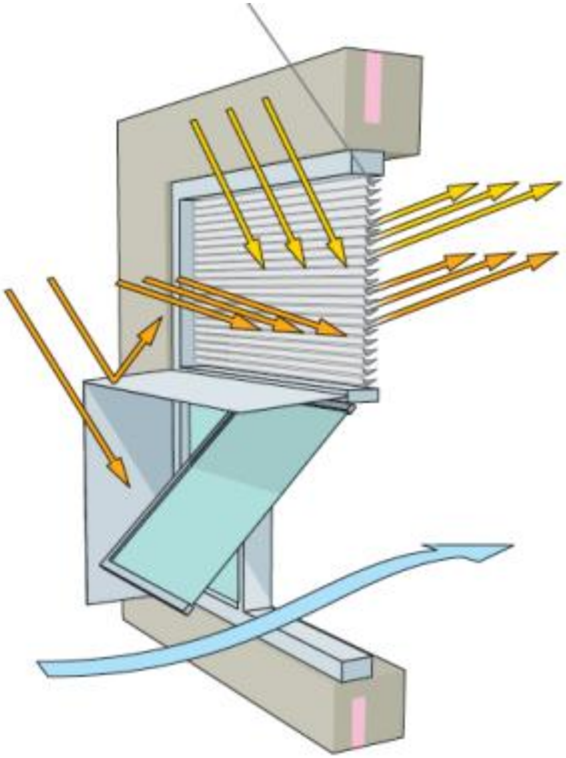
- Two long 60-foot wide wings with east-west orientation
- Design reduces electrical lighting

Daylighting: Glare Control

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

Fixed sunshades limit excess light and glare.



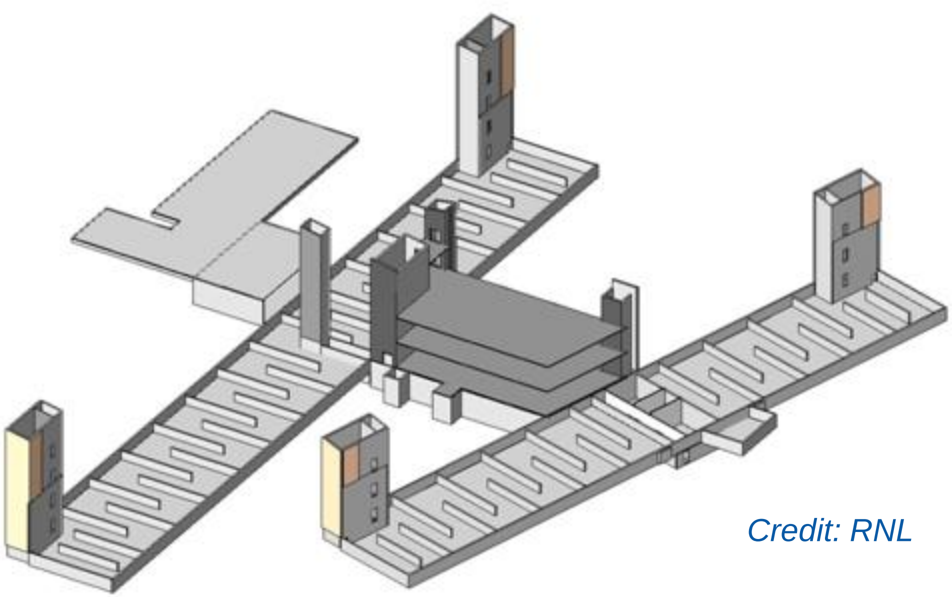


Credit: RNL

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.



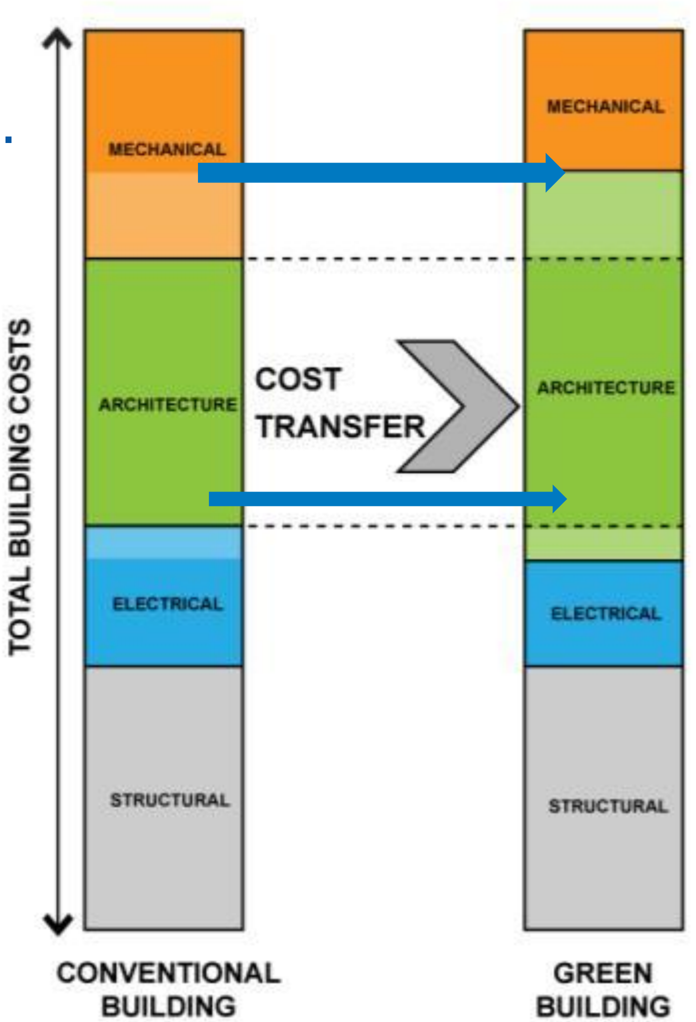
Credit: RNL

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

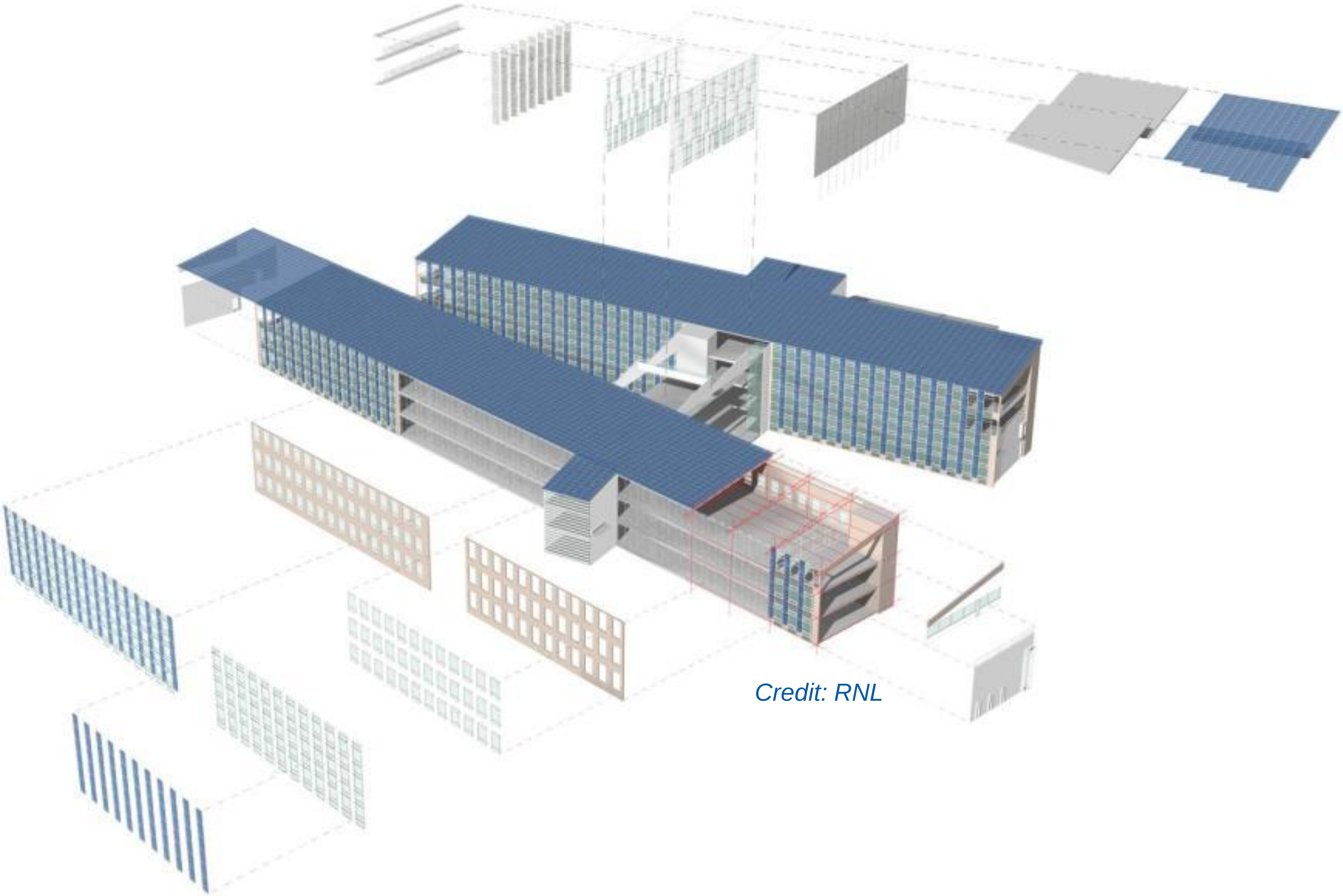
Design Best Practices

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

Focus on repeatable design elements.

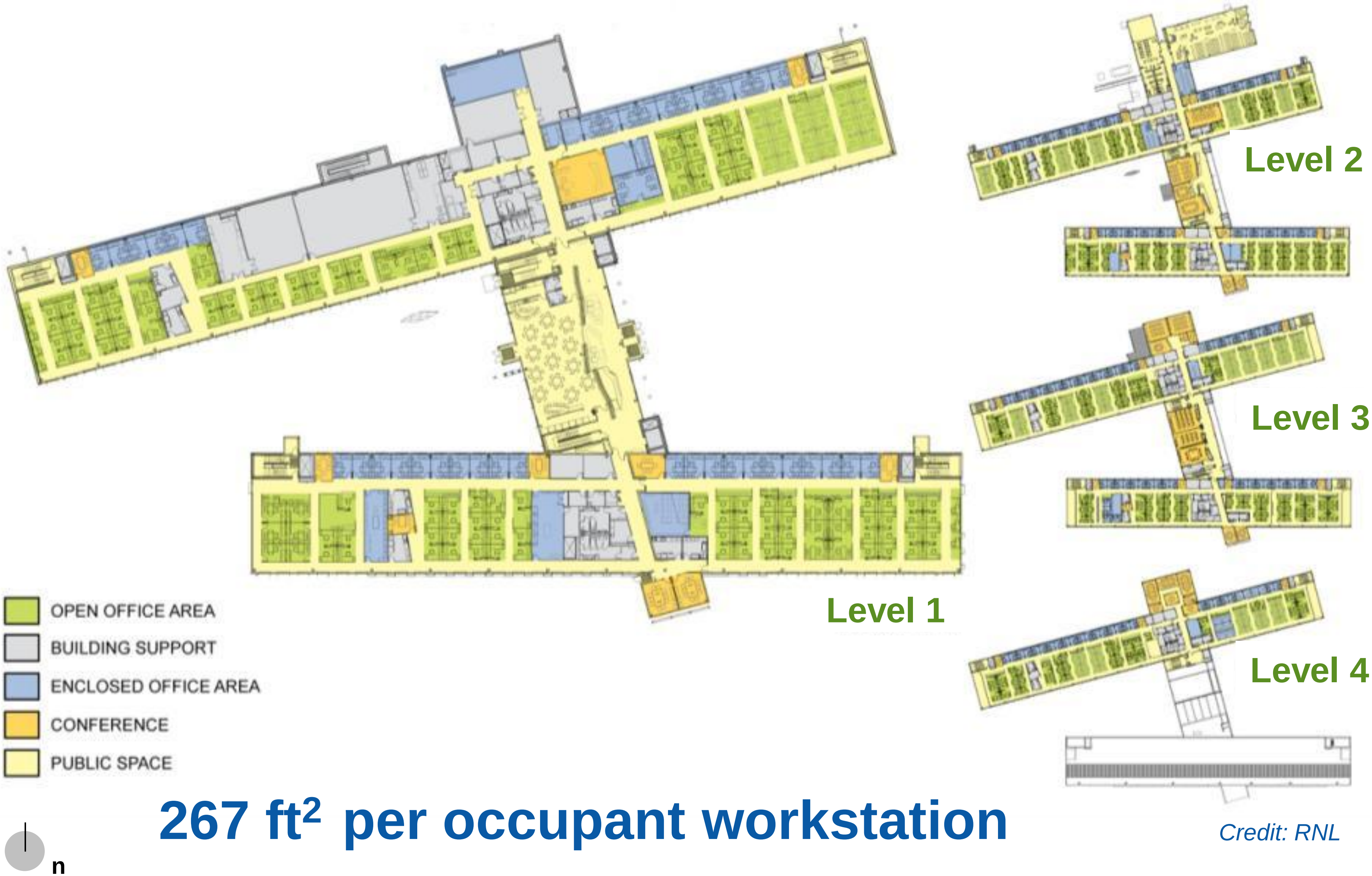
- Minimize unique and expensive building elements
- No curved walls
- Punched windows
- Increase space efficiency

Modular Design: Kit of Parts



Credit: RNL

Modular Floor Plans



267 ft^2 per occupant workstation

Credit: RNL

Modular Office Space

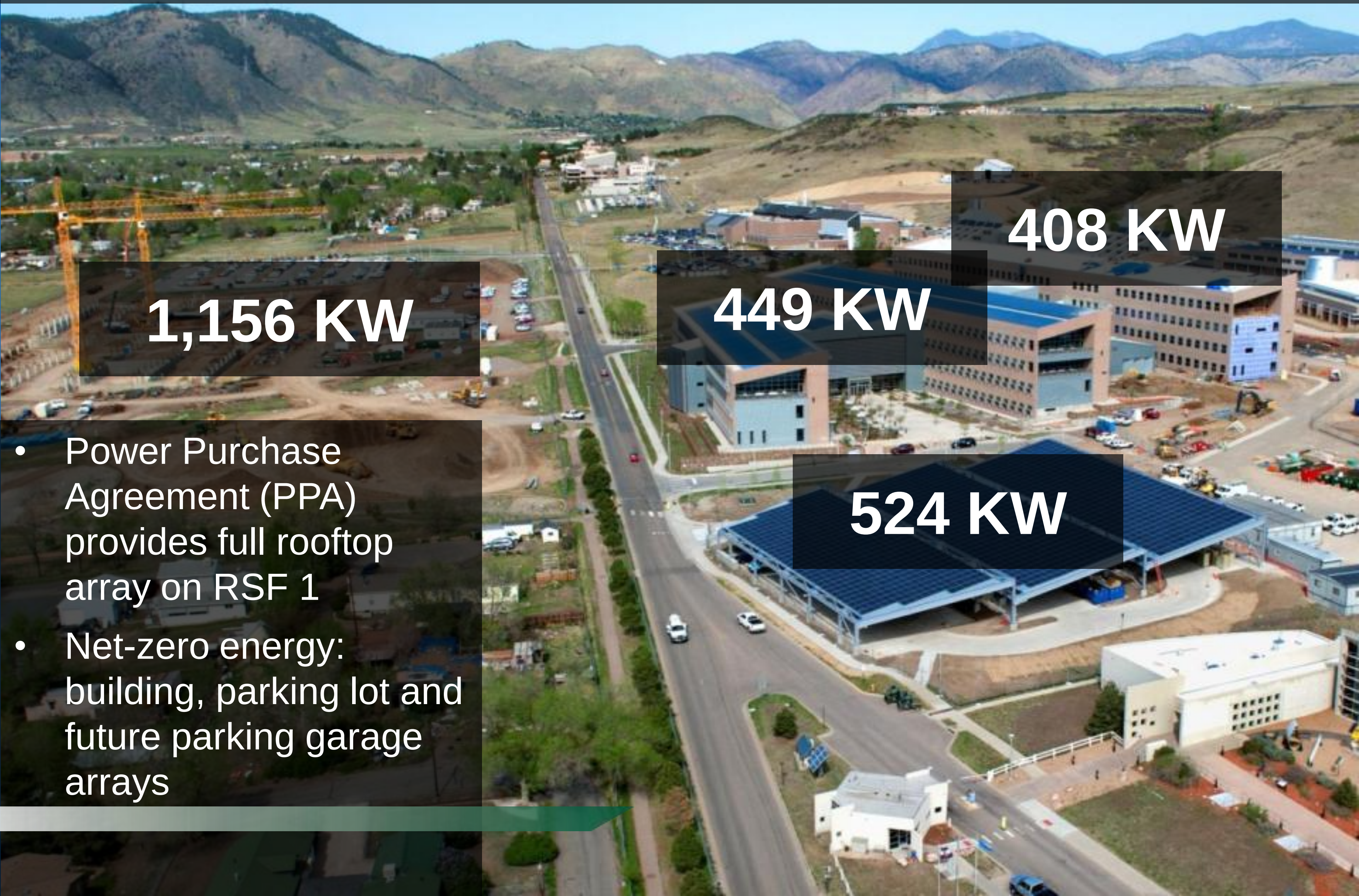
- Maximizes space efficiency
  - Allows for 72 ft^2 and 120 ft^2 office cubicles
- Reduces drywall costs
- Building designed around 30 ft x 60 ft office space modules

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

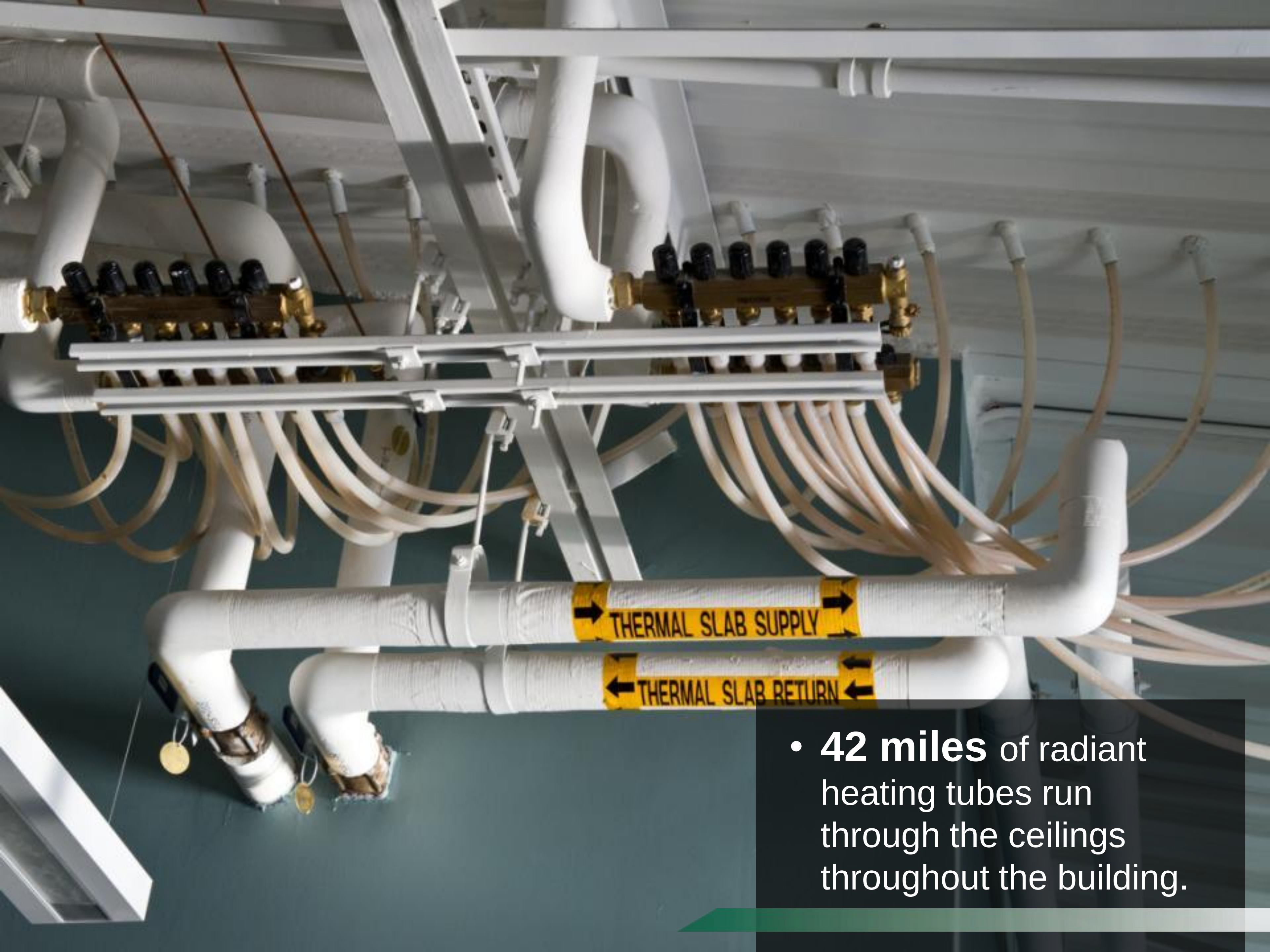
#13. Maximize use of off-site modular construction and building component assembly.

- Off-site assembly reduces on-site construction time
  - Faster site assembly
- Increases quality and reduces costs
- Minimizes site coordination details and safety concerns

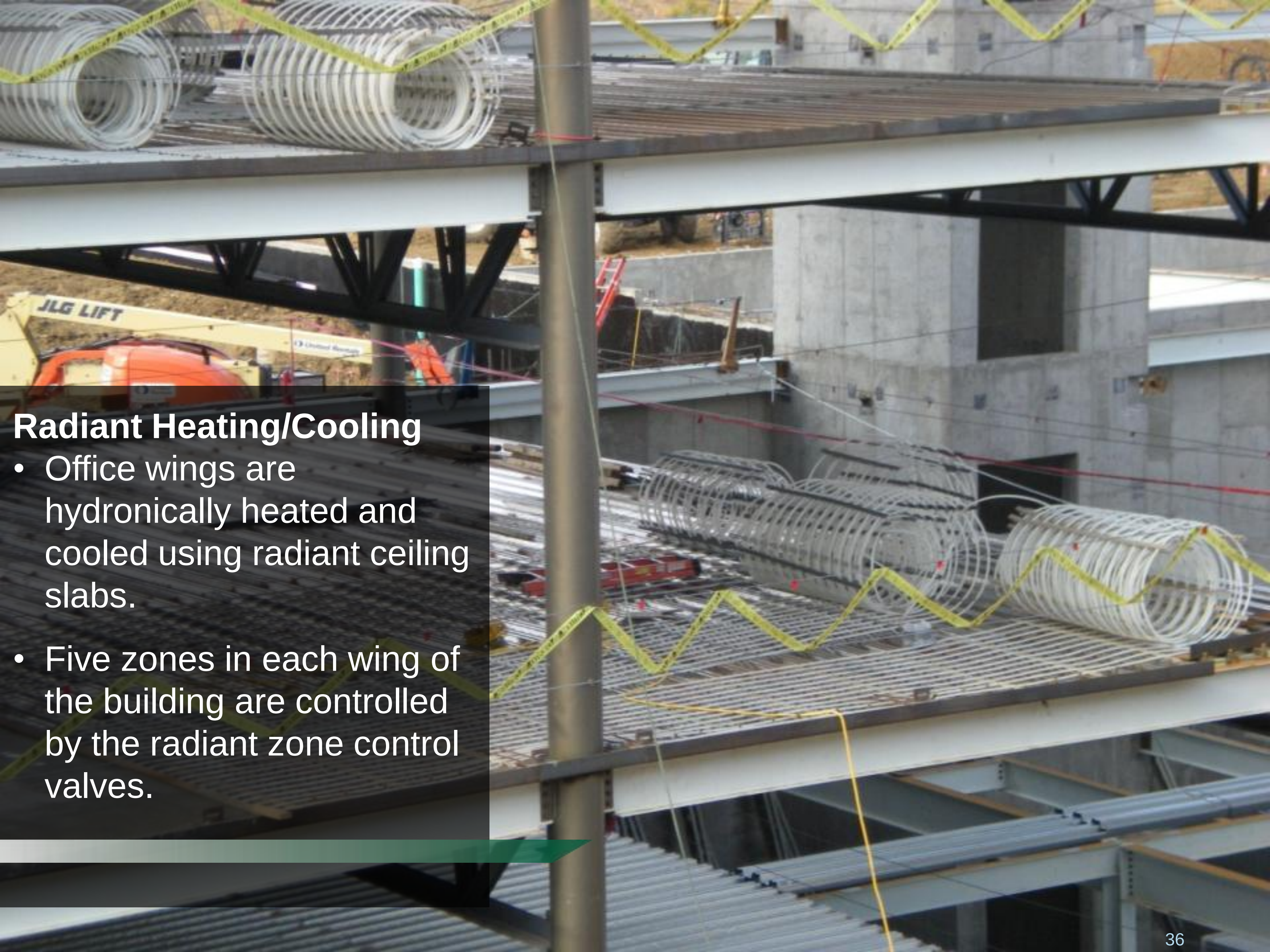
Precast Wall System

- 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.

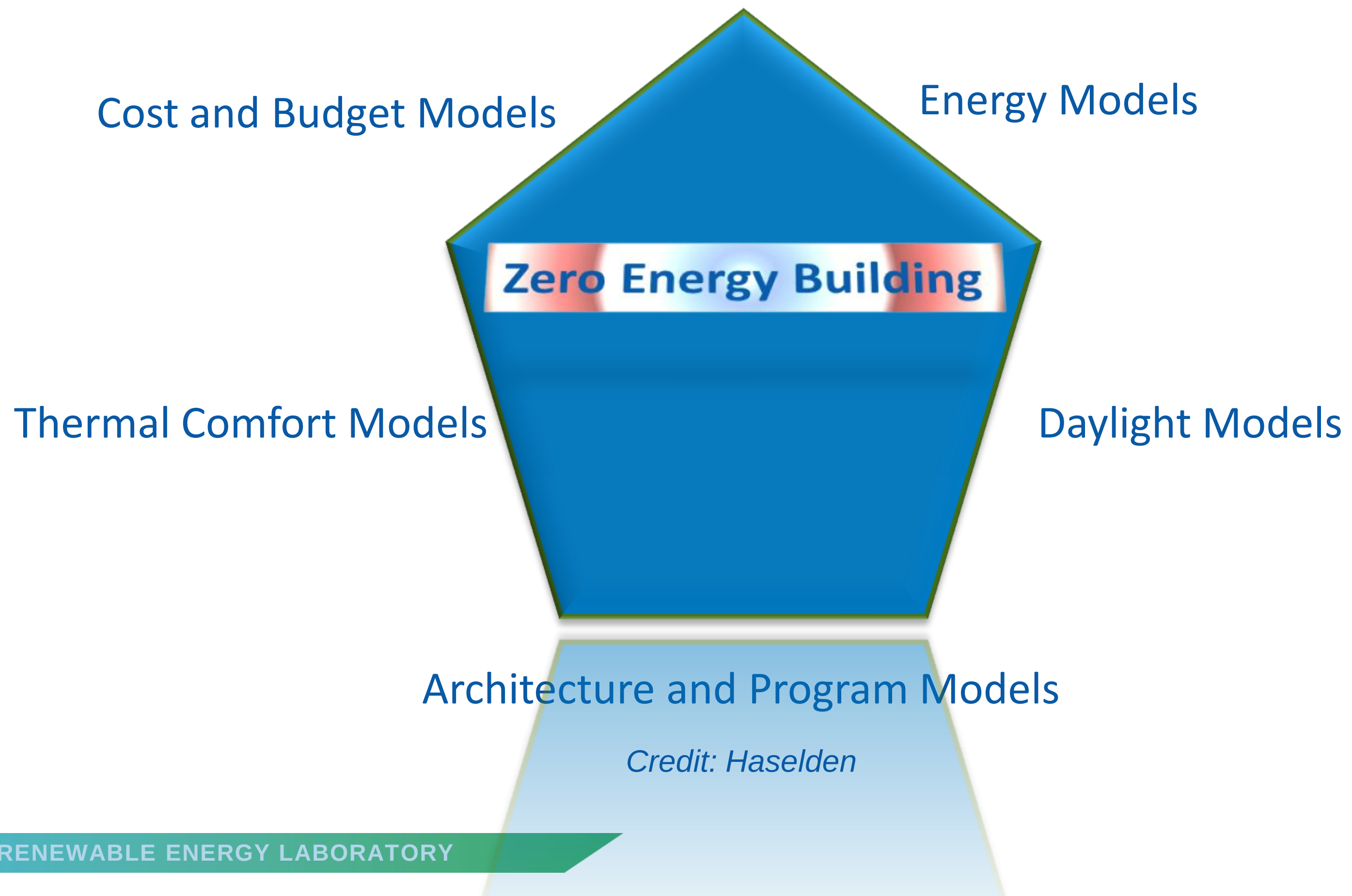
A Value Addition Process

View looking East into the Entry Plaza

Constructing Zero Energy

Integrated Design and Construction

5-Sided Problem Solving



Credit: Haselden

Construction Best Practices

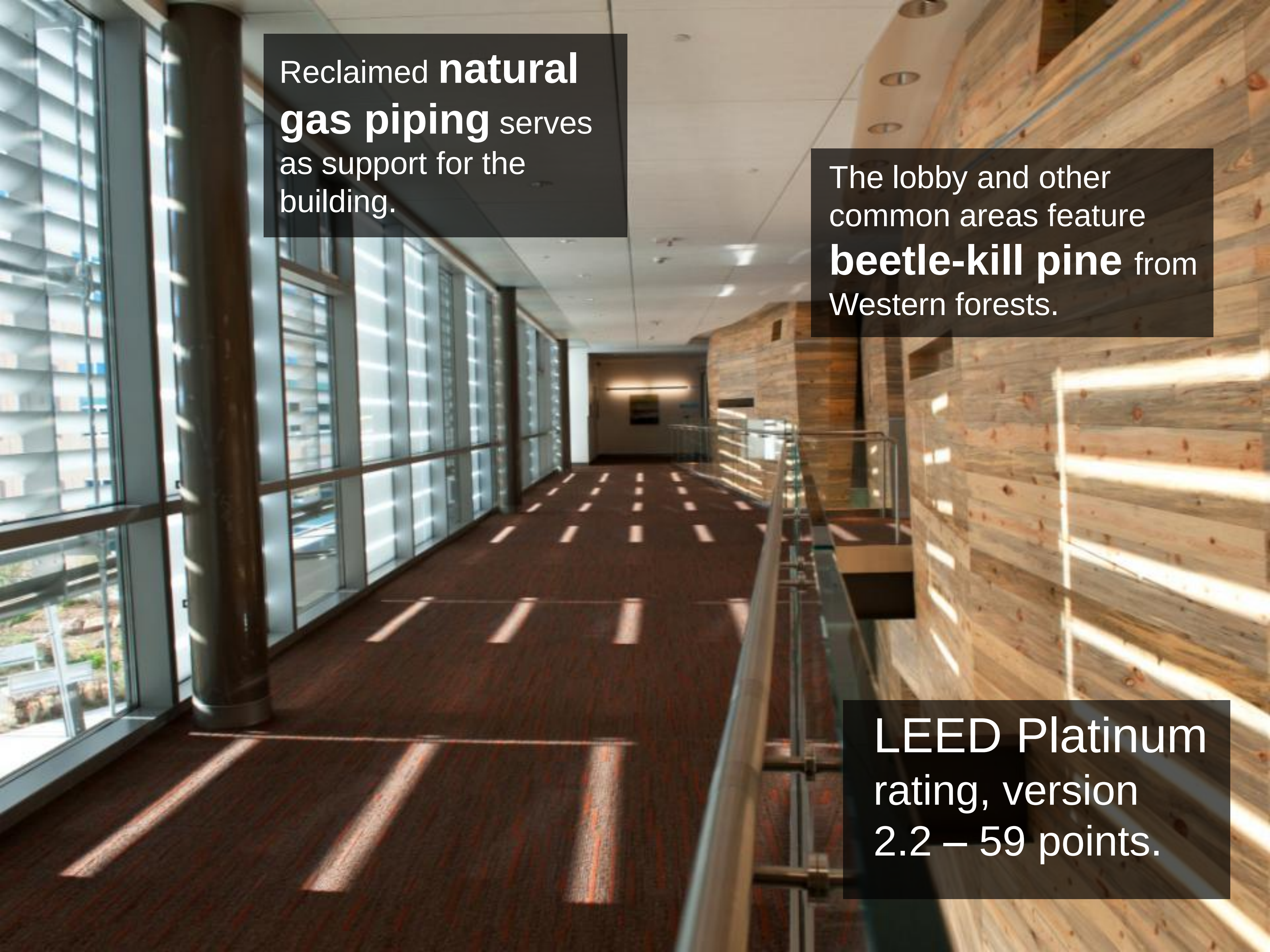
#15. Integrate experienced key subcontractors early in the design process.

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…

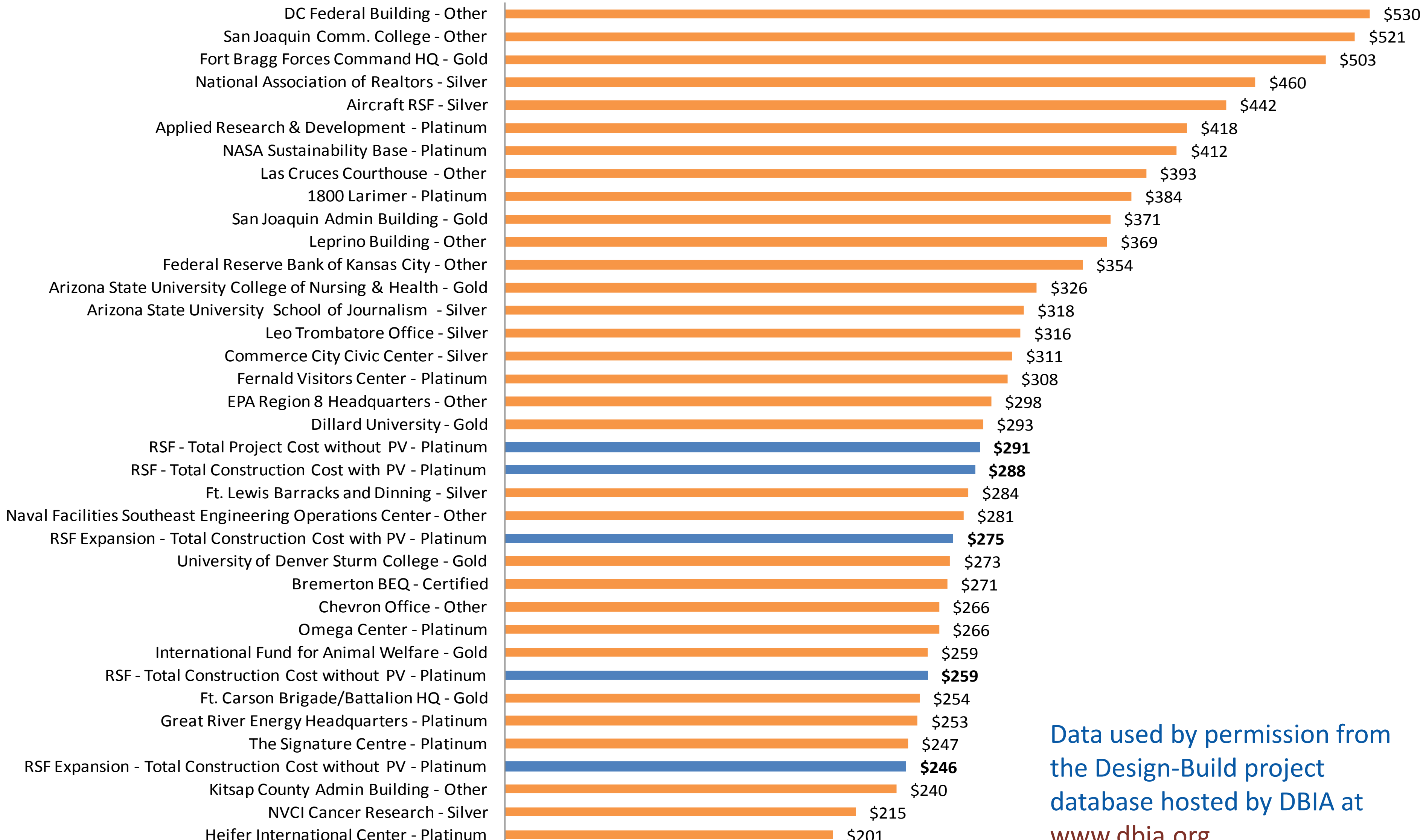
- Received elements/value that were not in the RFP (or did not help the energy efficiency)
  - Fancy woodwork detail
  - Extra glazing
- Comparison with other costs


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/ft^2 construction costs for site work, infrastructure, and building
  - Includes interiors, furniture, and cabling
  - Does not include PV, land, or design costs
- Third-party-owned power purchase agreement for PV
  - $29/ft^2 or 11% additional cost if NREL had purchased all PV without tax breaks or subsidies (at $5/Watt)

Compare



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
  - Set budget
  - Sought maximum value for that budget
  - Prioritized goals
- Design-build procurement process
  - Managed the team to the RFP and its substantiation criteria
  - 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

Shanti Pless

shanti.pless@nrel.gov

Paul Torcellini

paul.torcellini@nrel.gov