# Energy Efficient Design in a Design-Build Project

Kevin Brettmann
Director, Science & Technology, JE Dunn Construction, @jedunn

Adam Denmark, AIA, LEED AP BD+C
Principal, SmithGroupJJR, @Adam_SGJJR

#NRELESIF

National Renewable Energy Laboratory (NREL)
**Energy Systems Integration Facility**
Golden, Colorado

# Vicon Business Media

Provider Number: L390

NREL Energy Systems Integration Facility: Design-Build Delivered Energy Performance

Course Number: LDC2013-T06

Kevin Brettmann, Dir. of Science & Technology, JE Dunn Construction
Adam Denmark, AIA, LEED AP BD+C, Principal, SmithGroupJJR

Tuesday, April 9, 2013,11:20 AM

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA

CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

---

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

# Course Description

Presenters will discuss how complex energy goals are being achieved for the Energy Systems Integration Facility (ESIF) at the U.S. DOE's National Renewable Energy Laboratory (NREL) using a design/build project delivery method.

The new ESIF will house advanced high bay labs, outdoor test facilities, a high performance computing data center, and one of the most energy efficient office buildings in the world.

# Learning Objectives

At the end of the this course, participants will be able to:

1. Understand how an integrated project team drives the delivery of aggressive energy goals.

2. Understand performance based Design Build procurement and delivery process.

3. Learn about the design strategies to achieve aggressive energy goals.

4. Understand the types of laboratory environments required for different energy research areas

# ESIF Overview
## At a Glance

## Integrated research including:

- Building and facility systems,
- Community power generation and microgrids,
- Utility generation, and
- Grids that incorporate renewable energy (solar, wind, hydrogen, advanced vehicles), energy efficiency technologies, electrical systems architecture, and grid interoperability

## Labs and Equipment

- 14 fully equipped laboratories
- REDB and Grid simulator
- Centralized SCADA Control Room
- Several outdoor test beds

## HPC Data Center

- 10,000 sf Data Center floorplate
- Petaflop scale supercomputer
- Insight Visualization Center

### ESIF Snapshot

- Cost: $135M
- Square feet: 182,500
- Occupants: 200
- Super computer: Petaflop-scale
- State-of-the-art electric systems simulation and visualization in an HPC environment
- Component and systems testing and validation at MW-scale powers
- Integration of functioning systems with utility system simulations for real-time, real-power evaluation of high penetration scenarios
- Construction complete: Spring 2013

# Hybrid Process

Aug 2008 | September 2008 | Summer 2009 | August 2009 | August 2009 | September 2009

RFQ

SHORTLIST

JE Dunn
SMITHGROUP

Mortensen
Leo A Daly

WhitingTurner
FLAD/Merrick

Quals

900 PAGES

CONCEPT DESIGN

COSTING

$$$$$$ $$$

$

Interview

‘BEST VALUE SELECTION’

$120 M ($98M)

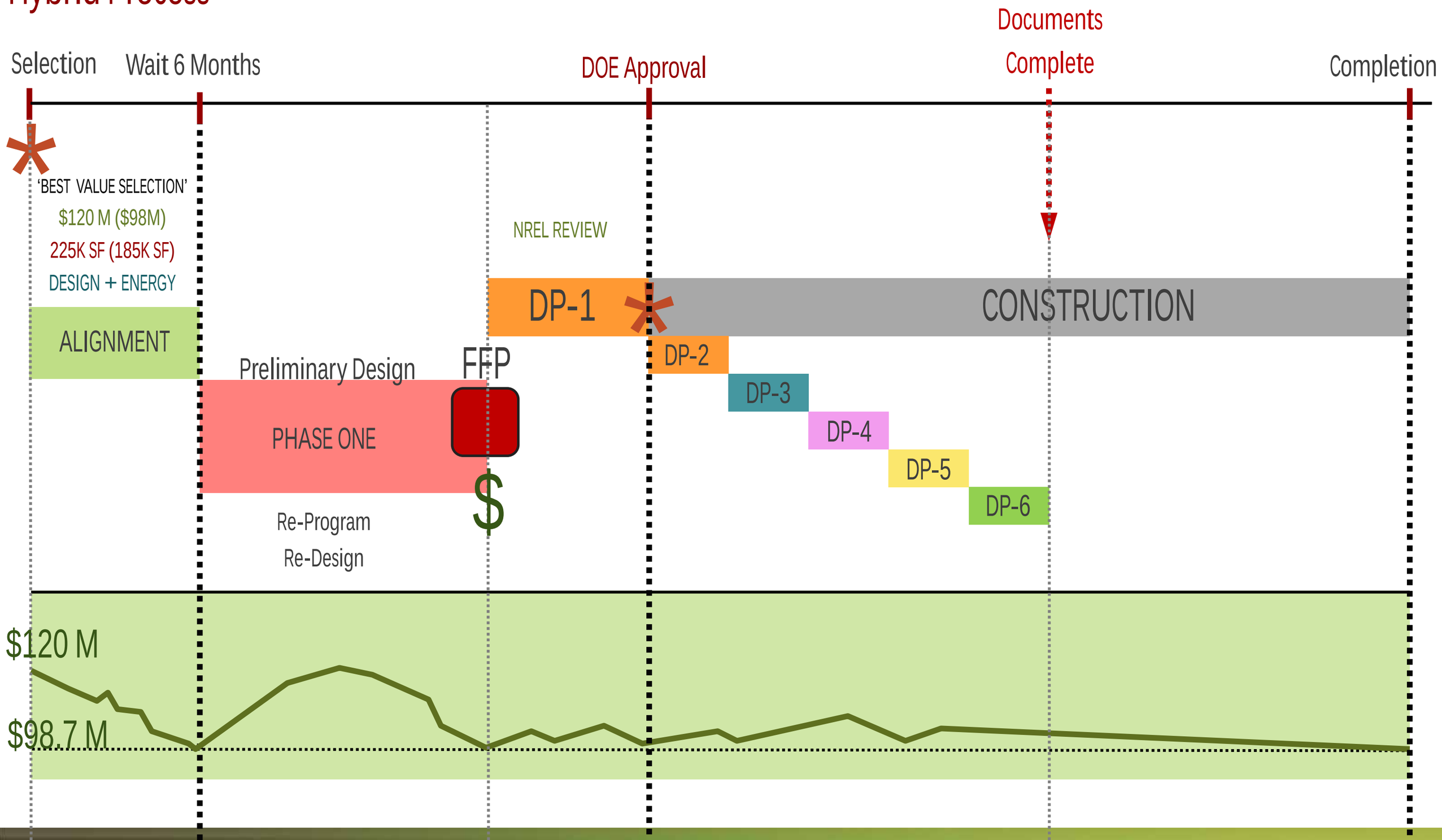
225K SF (153K SF)

DESIGN + ENERGY

# The Bible


Energy Systems Integration Facility
Systems Integration
Request for Proposals
RFI-9-88648
27 May 2009
NREL
National Renewable Energy Laboratory
1617 Cole Boulevard - Golden, Colorado 80401

# Hybrid Process



# What We're Bringing to the Table

## Priority Checklist

| REQUIRED - Request for Proposal Submission | Provided in the RFP Y/N | Rank |
|---|---|---|
| Design and build the facility by integrating safety including operational safety, fire protection and life safety into every phase of the project including design, construction and anticipated use. | Y | 1 |
| Accommodate all laboratories, a 200 person office and the High Performance Computing Center (HPCDC) described in the program. | Y | 2 |
| Achieve an annualized Power Use Effectiveness (PUE) of 1.06 or lower and an annualized Energy Use Effectiveness of 0.9 or lower for the HPCDC. | Y | 3 |
| Key Subcontractors, Personnel and Projects for the Mechanical Electrical Plumbing (MEP) Team and the High Performance Computing Data Center (HPCDC)Team. | Y | 4 |
| Provide a schedule with guaranteed Substantial Completion date of October 2011. | Y | 5 |
| REQUIRED - After Subcontract Award | Y | |
| Excess waste heat from the data center above that which is used to heat the facility is exported for use by the remainder of the campus. | Y | 6 |
| Research equipment identified in the Program will be state-of-the art at the time of occupancy. | Y | 7 |
| Utilize state of the art integrated electrical control systems and displays for the distributed energy laboratories, visualization centers and control rooms. | Y | 8 |
| GOALS | Y | |
| Achieve an average annualized EUE of 0.6 or less for the HPCDC. | Y | 9 |
| 250 staff office space capacity. | Y | 10 |
| An additional 2,000 SF laboratory similar to the Smart Grid Laboratory within the allowed budget. | Y | 11 |
| An additional 1,500 SF laboratory similar to the Fuel Quality Laboratory within the allowed budget. | Y | 12 |
| Maximize laboratory flexibility to support future technologies. | Y | 13 |
| Achieve LEED™ Platinum for the entire facility. | N → Y | 14 |
| A facility conducive to captivating and informative tours for up to 20 visitors without disrupting ongoing | Y | 15 |
| Visual displays of current facility energy efficiency. | Y | 16 |
| Most energy efficient data center in the country. | Y | 17 |
| Achieve national and global recognition and awards. | Y | 18 |

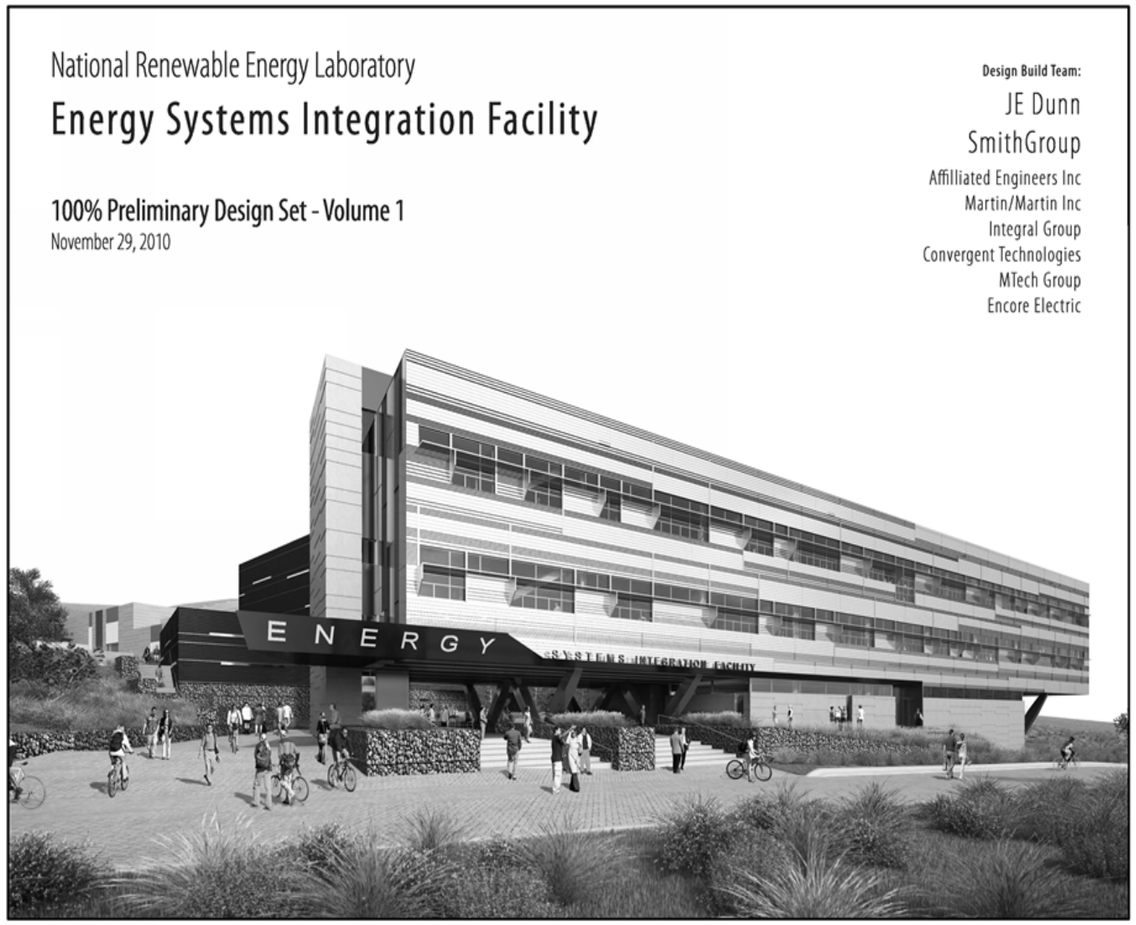
## Guiding Principles

- ✓ Safety
- ✓ Flexibility
- ✓ Sustainability
- ✓ Quality
- ✓ Value
- ✓ Schedule

# Preliminary Performance Baseline Design Submission

## Requirements:

- Drawings
- Specs
- Substantiation
- Preliminary Energy Model
- Commissioning Plan
- Quality Assurance Plan
- Preliminary Process Hazards Analysis
- Cost Loaded Schedule
- Preliminary Risk Register
- Certified Cost or Pricing Data (7 volumes w/ full detail)
- Firm Fixed Price ($97,748,707) – Significant Risk for D/B Team!




** Successful Preliminary Performance Baseline Submitted on December 7, 2010

# Substantiation

## Show me the proof!

- 425 items
- Some items redundant with drawings and specs (lighting analysis required separate study with calculations, presentations, etc)
- 3 months to close out NREL comments (multiple iterations)
- Measurement & Verification remaining
- Organization is key!

| | Target | DP-3 |
|---|---|---|
| HPCDC Annual Power Usage Effectiveness (PUE) | 1.06 | 1.04 |
| HPCDC Annual Energy Usage Effectiveness (EUE) | 0.9 | 0.7 |
| ASHRAE 90.1, 2007 | 30% better | 34% |
| Office Space Annual Average Energy Use Density (kBTU/sf/yr) | 26.7 | 23.0 |

**SUBSTANTIATION SUMMARY FORM**

TITLE AND LOCATION
Energy Systems Integration Facility, National Renewable Energy Laboratory, Golden, CO

| | | | TYPE OF SUBMITTAL | | | | | | | | | | | CLASSIFICATION | | PROJECT PHASE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SECTION | PARAGRAPH NUMBER | DESCRIPTION OF ITEM SUBMITTED | 01 - PRECON SUBMITTALS | 02 - SHOP DRAWINGS | 03 - PRODUCT DATA | 04 - SAMPLES | 05 - DESIGN DATA | 06 - TEST REPORTS | 07 - CERTIFICATES | 08 - MFRS INSTRUCTIONS | 09 - MFRS FIELD REPORT | 10 - O&M DATA | 11 - CLOSEOUT SUBMITTAL | FOR INFORMATION ONLY | GOVERNMENT APPROVED | PreliminaryDesign | Design Development | Construction Documents | Construction | Commissioning/Close-out |
| 111 | A4c13 | LEED Checklist annotated to show specific credits status of design related to specific credits to be achieved. | | | | | | | | | | | | | | x | x | x | | |
| 111 | A4c1a | Sustainability Design Report to include annual energy consumption calculations for the base-case building ar the proposed case building. | | | | | | | | | | | | | | | x | | | |
| 111 | A4C3b | Comprehensive checklist of certification documentatio specified in LEED Reference Guide, annotated to show which forms of documentation have been submitted | | | | | | | | | | | | | | | x | x | | |
| 111 | A4c3c | Documentation specified in LEED Reference Guide th is relevant to the degree of completion of the design | | | | | | | | | | | | | | | x | x | | |
| 111 | A4c1b | 10 page maximum narrative describing how the Design Builder proposes to achieve PUE and EUE goals | | | | | | | | | | | | | | | x | x | | |
| 111 | A4c1c | ASHRAE 140 compliant energy model using NREL provided weather file | | | | | | | | | | | | | | | x | x | | |
| 111 | A4c4a | Submit LEED application and pay applicable fees. | | | | | | | | | | | | | | | | | | x |
| 111 | A4c4b | Provide all certification documentation and install certification plaque. | | | | | | | | | | | | | | | | | | x |
| 111 | A4c4c | Provide Owner a complete duplicate of certification documentation | | | | | | | | | | | | | | | | | | x |
| 111 | C2b1 | For load-resisting elements, structural design calculations and drawings sealed by licensed structura engineer | | | | | | | | | | | | | | | | | x | |
| 111 | C3c1 | If methods prescribed by NFPA 780 are not used, description of engineering basis of design, including grounding terminal design | | | | | | | | | | | | | | | x | | | |
| 111 | C3c2 | If grounding in very shallow or dry soil, or in rock, is required, ground resistance measurements and engineering analysis of ground terminal design | | | | | | | | | | | | | | | x | | | |
| 111 | C3c3 | Diagrams showing locations of strike (air) terminals ar zones of protection; identification of internal componen that require bonding to equalize potential | | | | | | | | | | | | | | | x | | | |
| 111 | C3c4 | Engineering analysis of equalization of potential to met bodies within the structure | | | | | | | | | | | | | | | | x | | |
| 111 | C3c5 | Drawings showing locations and sizes of conductors, bonding of metal bodies, and components; detailed installation specifications | | | | | | | | | | | | | | | | x | | |
| 111 | C3c6 | Continuity tests for grounding conductors, equipotentia bonding of other systems, and ground terminals; groun resistance test for each ground terminal, or equivalent taking into account related grounding systems | | | | | | | | | | | | | | | | | | x |
| 111 | C3c7 | Certification of system complying with UL Master Labe or Lightning Protection Institute Certified System requirements | | | | | | | | | | | | | | | | | | x |
| 111 | C3c8 | Maintenance and inspection procedures | | | | | | | | | | | | | | | | | | x |
| 111 | C3d9 | Project record data; location of ground terminals, groun resistance and soil conditions at time of test | | | | | | | | | | | | | | | | | | x |
| 111 | C4c2a | Identification of methods to be used to comply with requirements; ventilation design calculations. Identification of unusual indoor contaminants or source and methods to mitigate their effects on occupants. | | | | | | | | | | | | | | | x | | | |
| 111 | C4c2b | Specifications showing that construction materials are not contaminant sources and do not adversely affect ai quality. Provide all documentation required by ANSI/ASHRAE 62.1-2004 | | | | | | | | | | | | | | | | x | | |

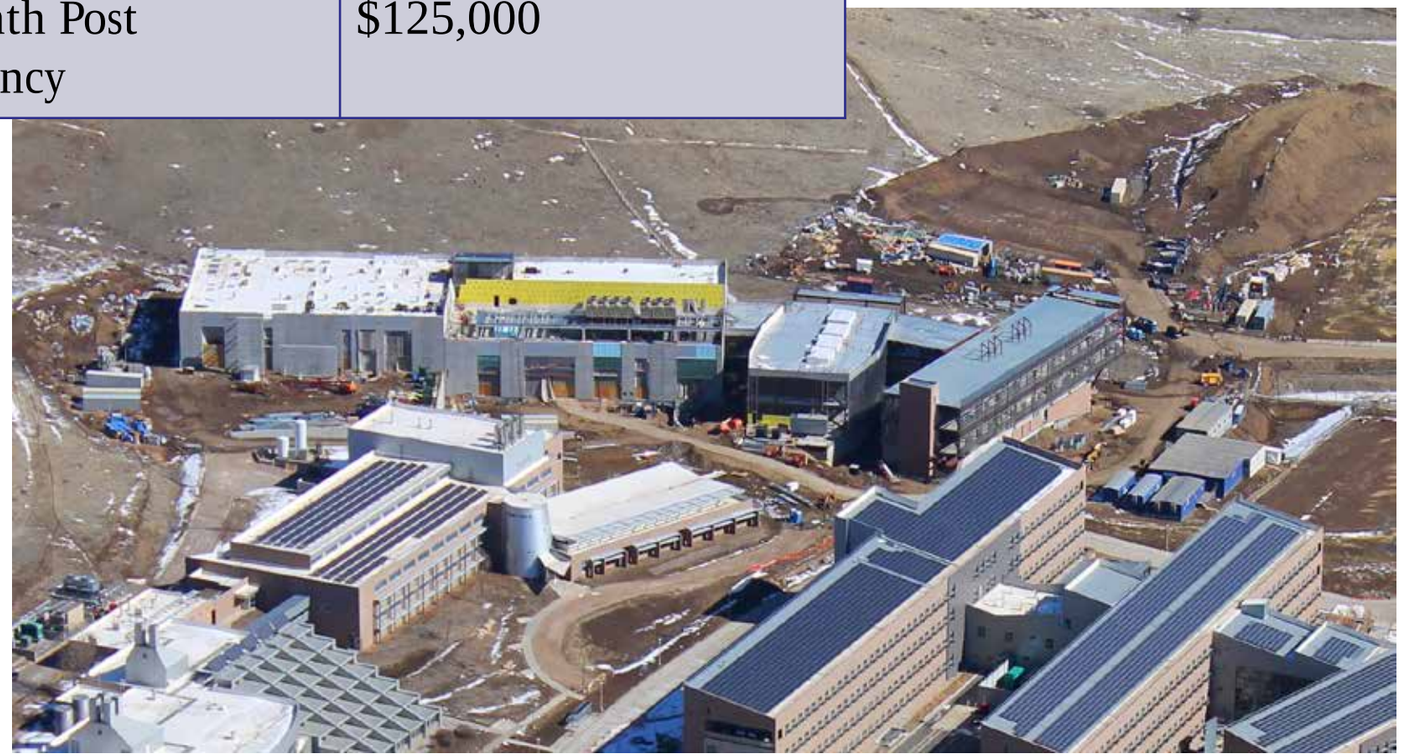
# Award Fee Incentive Program

To Promote Excellent Performance by the Design-Builder

## 6 Evaluation Periods

** NREL reserves the right to "rollover" any unearned Award Fee to the next evaluation stage.

| | |
|---|---|
| Preliminary Design | $500,000 |
| Design Development | $375,000 |
| Construction Documents | $375,000 |
| Substantial Completion | $750,000 |
| Closeout | $375,000 |
| 12 Month Post Occupancy | $125,000 |



# Current Project Status

## 6 Design Packages

- ü DP-1: Foundations, Excavation, Utilities, Precast, Structural Steel
- ü DP-2: Core & Shell
- ü DP-3: Lab Fitout, Interior Finishes
- ü DP-4: Furniture & Signage
- ü DP-5: REDB
- ü DP-6: SCADA

# It Takes a Village!

# Overall Performance Targets

A High Profile Facility of National Importance

LEED Platinum for the entire Facility

Integrated & Sustainable High Performance Design

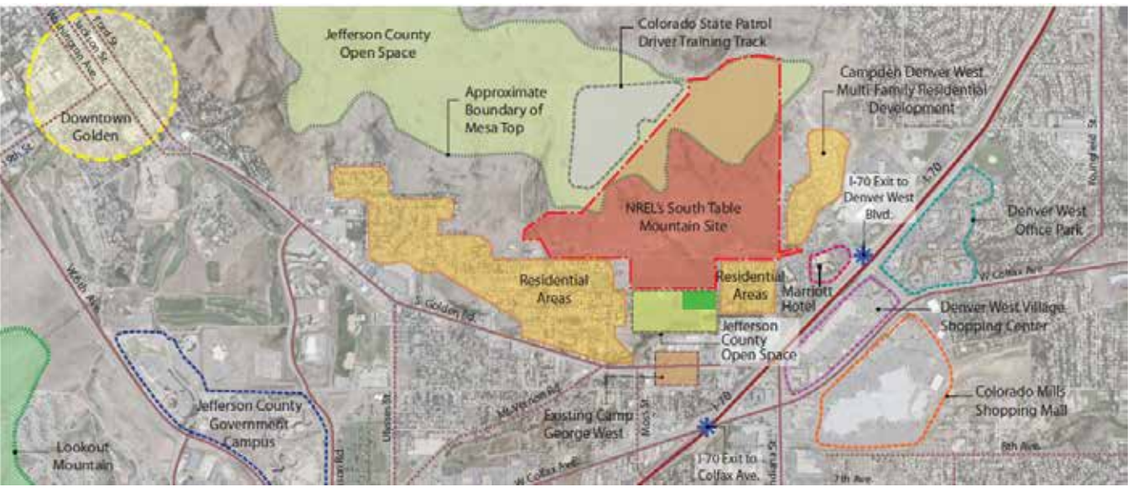
National Showcase of Sustainable High Performance Design

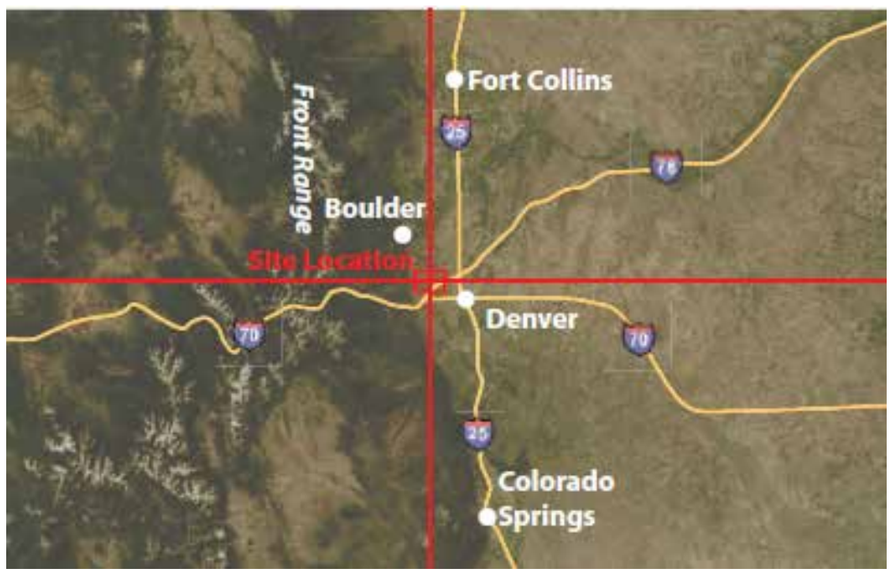
Optimized Energy Use & Re-Use within Building & Campus

The Most Energy Efficient Data Center in North America

| REQUIRED - Request for Proposal Submission | Provided in the RFP Y/N | Rank |
|---|---|---|
| Design and build the facility by integrating safety including operational safety, fire protection and life safety into every phase of the project including design, construction and anticipated use. | | 1 |
| Accommodate all laboratories, a 200 person office and the High Performance Computing Center (HPCDC) described in the program. | | 2 |
| Achieve an annualized Power Use Effectiveness (PUE) of 1.06 or lower and an annualized Energy Use Effectiveness of 0.9 or lower for the HPCDC. | | 3 |
| Key Subcontractors, Personnel and Projects for the Mechanical Electrical Plumbing (MEP) Team and the High Performance Computing Data Center (HPCDC) Team. | | 4 |
| Provide a schedule with guaranteed Substantial Completion date of October 2011. | | 5 |
| REQUIRED - After Subcontract Award | | |
| Excess waste heat from the data center above that which is used to heat the facility is exported for use by the remainder of the campus. | | 6 |
| Research equipment identified in the Program will be state-of-the art at the time of occupancy. | | 7 |
| Utilize state of the art integrated electrical control systems and displays for the distributed energy laboratories, visualization centers and control rooms. | | 8 |
| GOALS | | |
| Achieve an average annualized EUE of 0.6 or less for the HPCDC. | | 9 |
| 250 staff office space capacity. | | 10 |
| An additional 2,000 SF laboratory similar to the Smart Grid Laboratory within the allowed budget. | | 11 |
| An additional 1,500 SF laboratory similar to the Fuel Quality Laboratory within the allowed budget. | | 12 |
| Maximize laboratory flexibility to support future technologies. | | 13 |
| Achieve LEED™ Platinum for the entire facility. | | 14 |
| A facility conducive to captivating and informative tours for up to 20 visitors without disrupting ongoing | | 15 |
| Visual displays of current facility energy efficiency. | | 16 |
| Most energy efficient data center in the country. | | 17 |
| Achieve national and global recognition and awards. | | 18 |

# Campus Integration



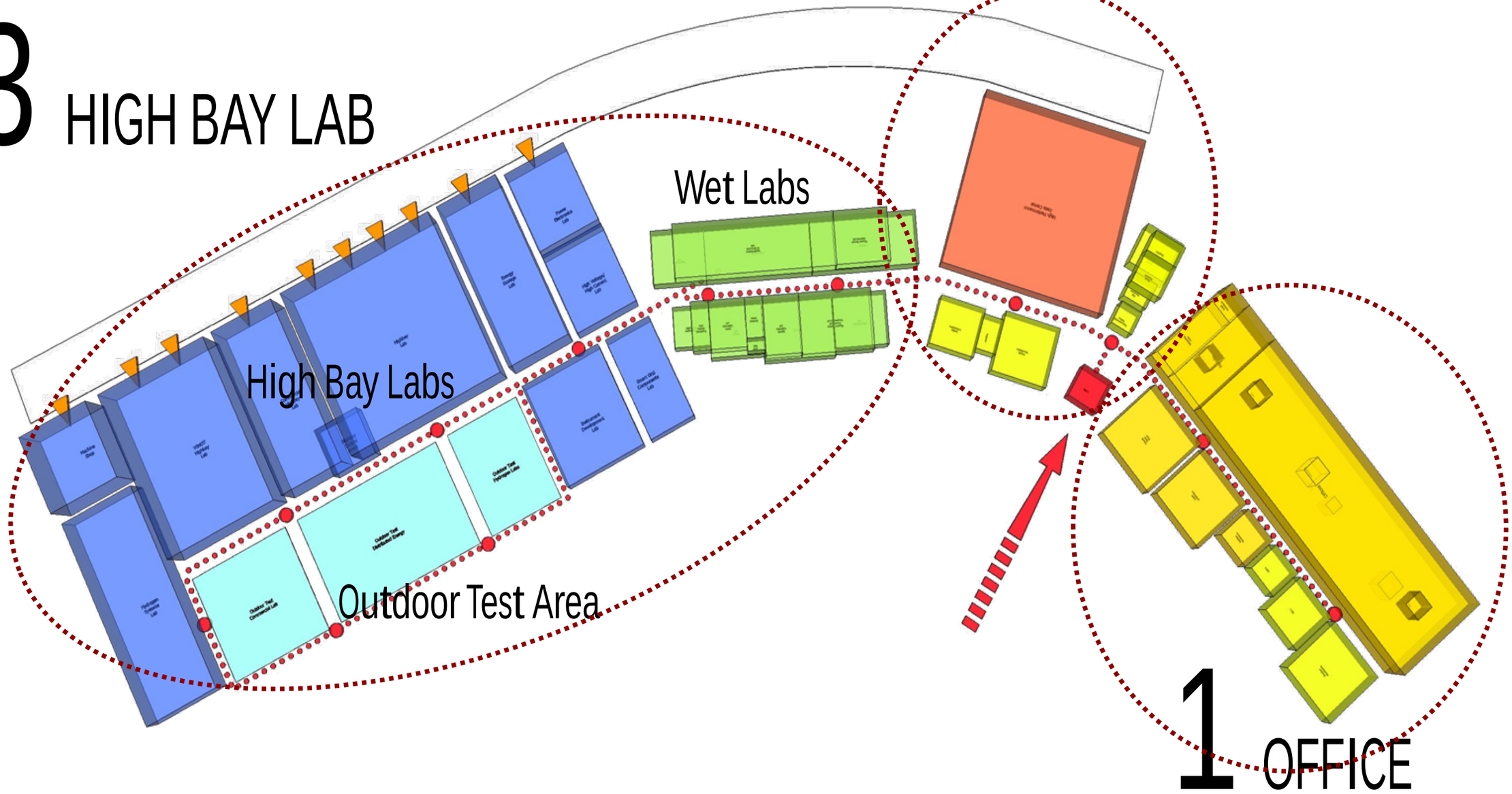




# Current Development

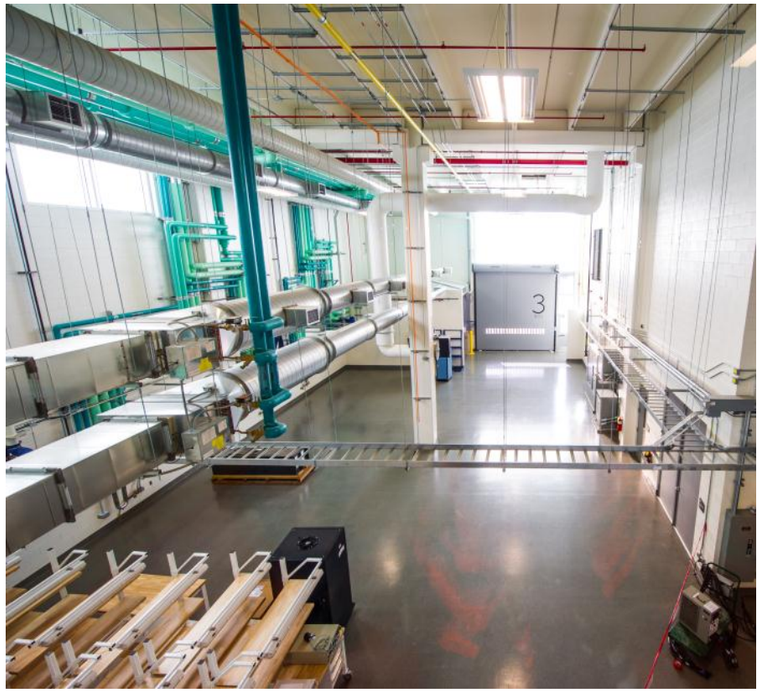
# The Program

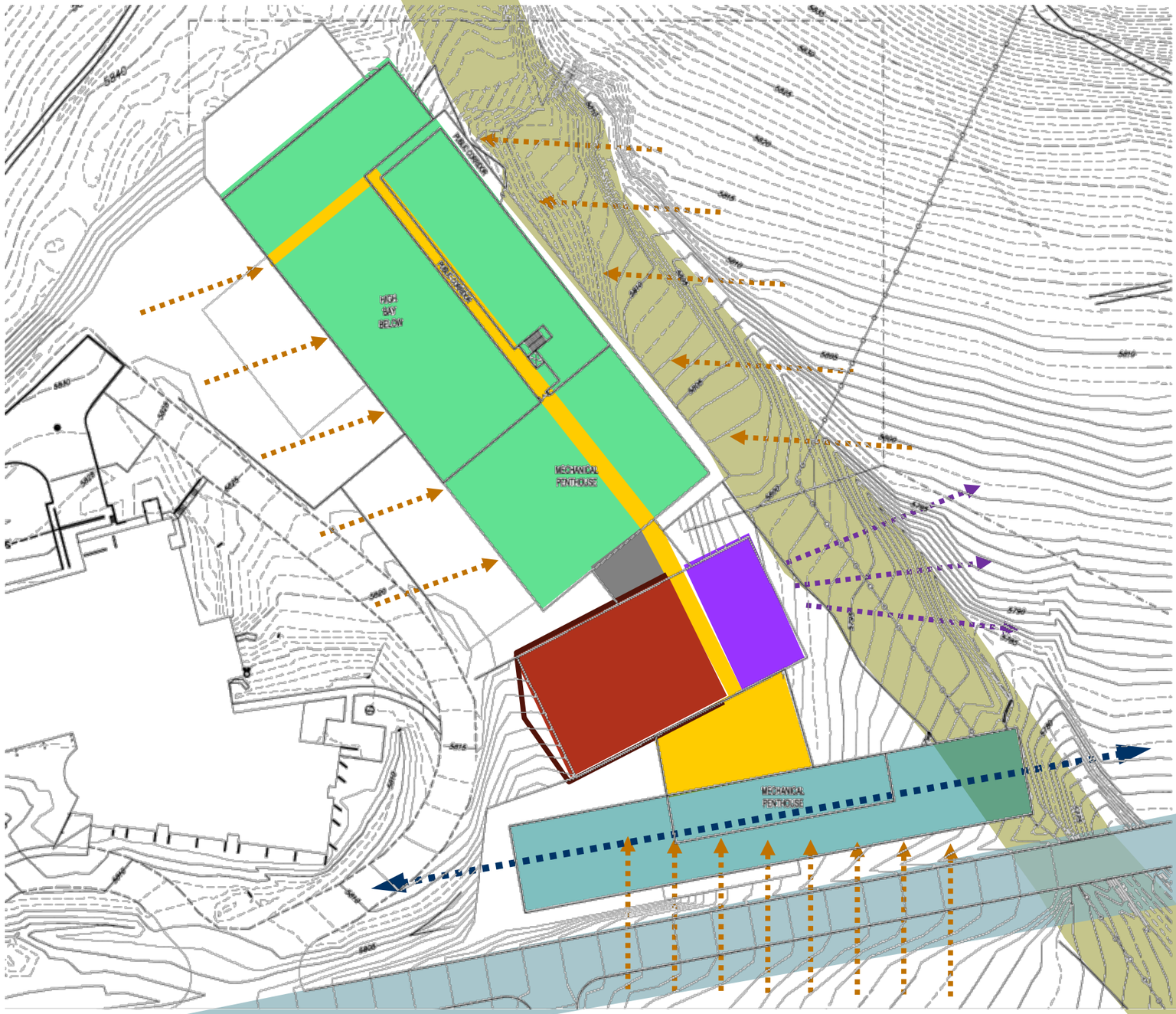
2 DATA CENTER

3 HIGH BAY LAB



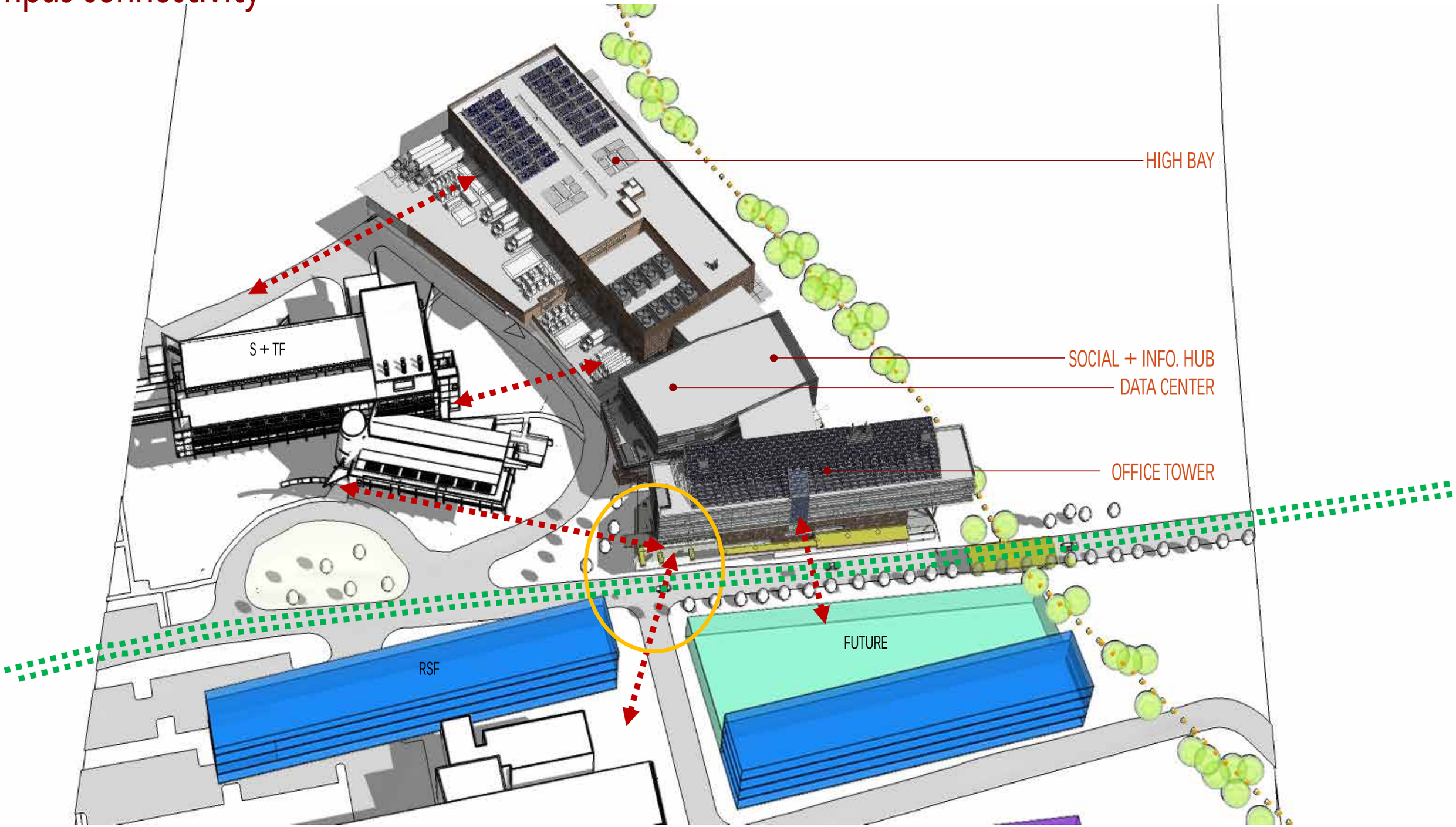
# Orientation, Daylighting + Natural Ventilation





# Site Topography

# Campus Connectivity



# Office

# Entry

# Courtyard

# Interior View

# Office

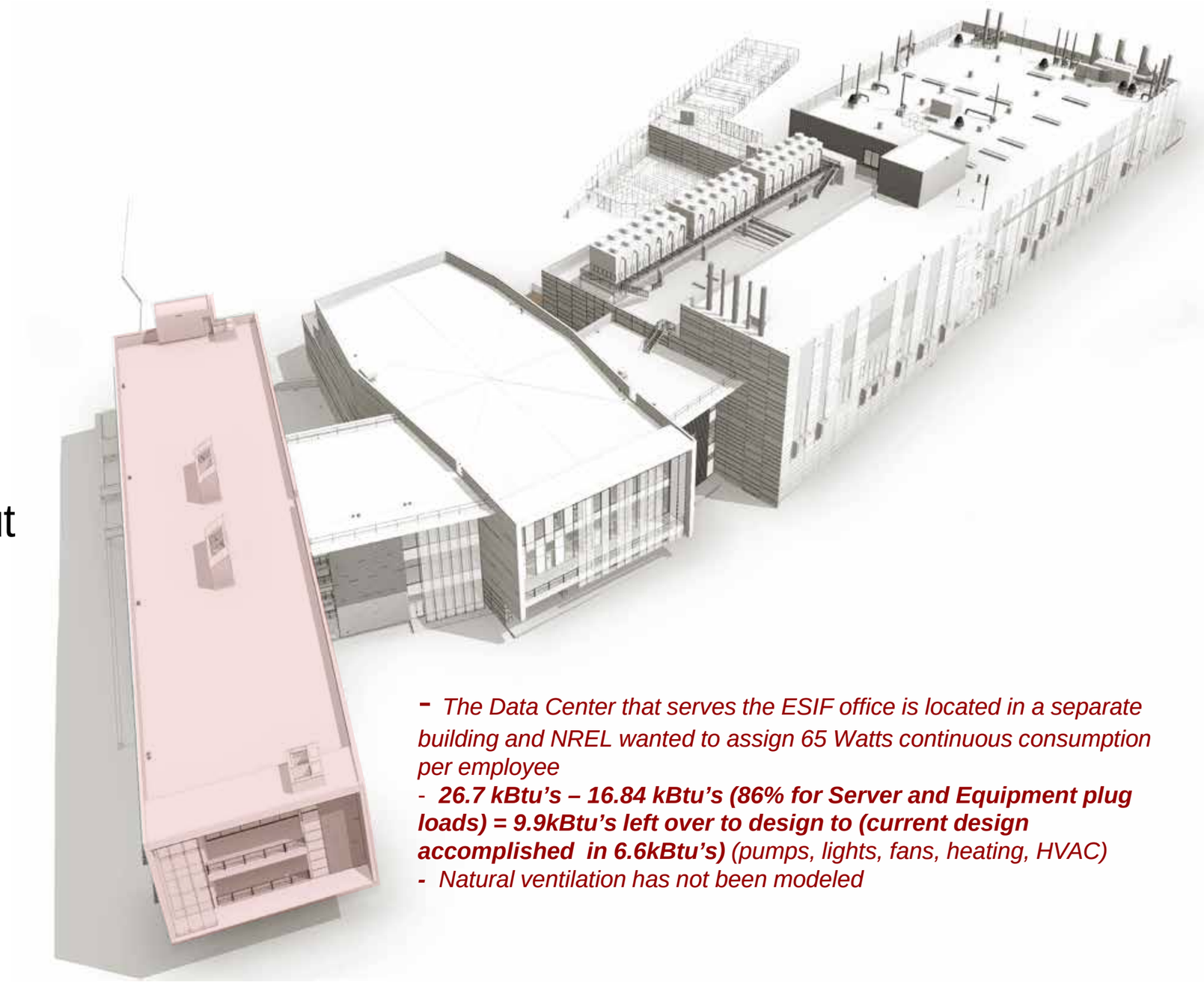
Energy Target (Site EUI): **26.7 kBTU/sf/yr**

National Average Site EUI: **90 kBTU/sf/yr** (CBECS)

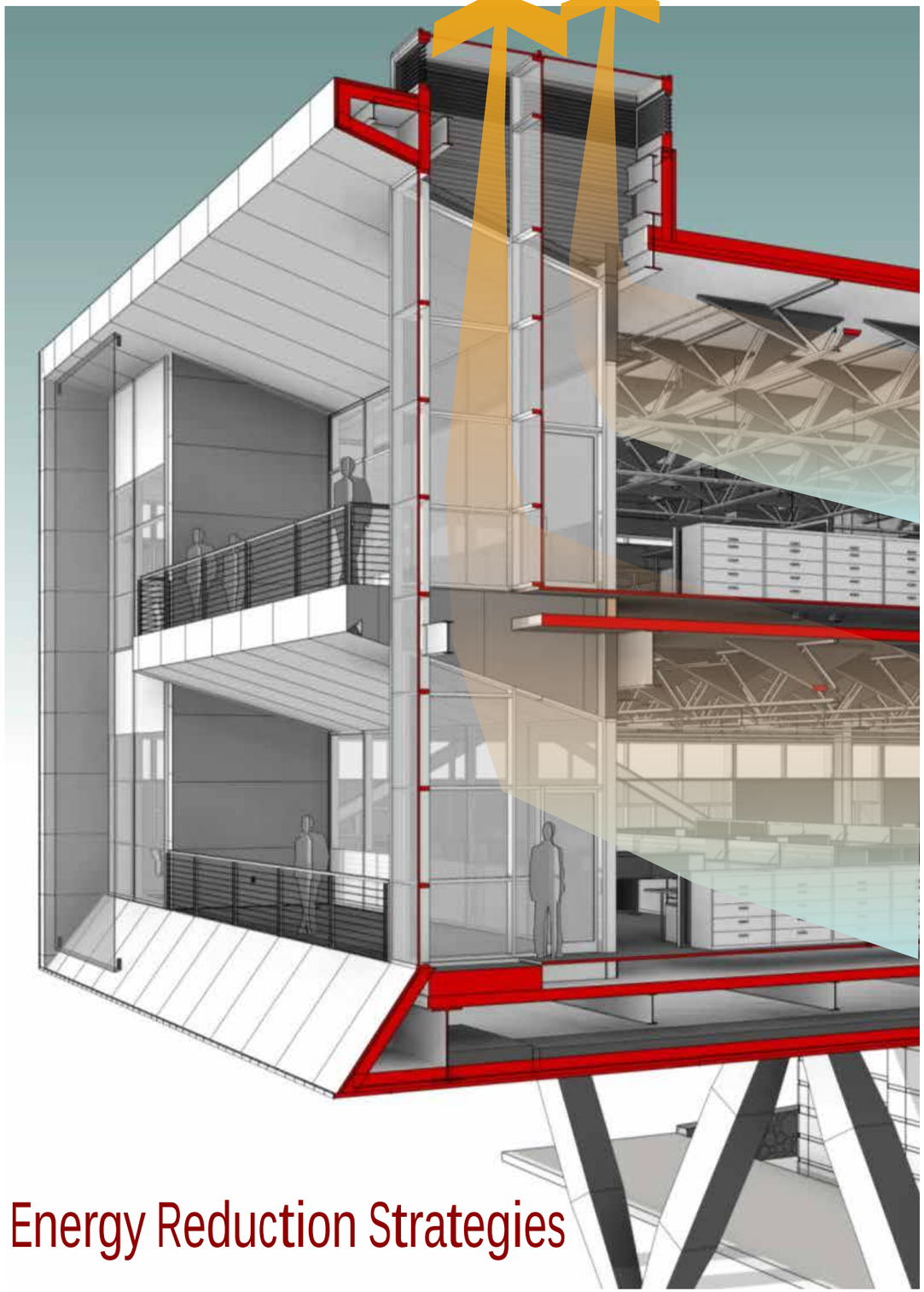
Energy Efficiency over National Average (w/server): **74%**

Energy Efficiency over National Average (w/out server): **87%**

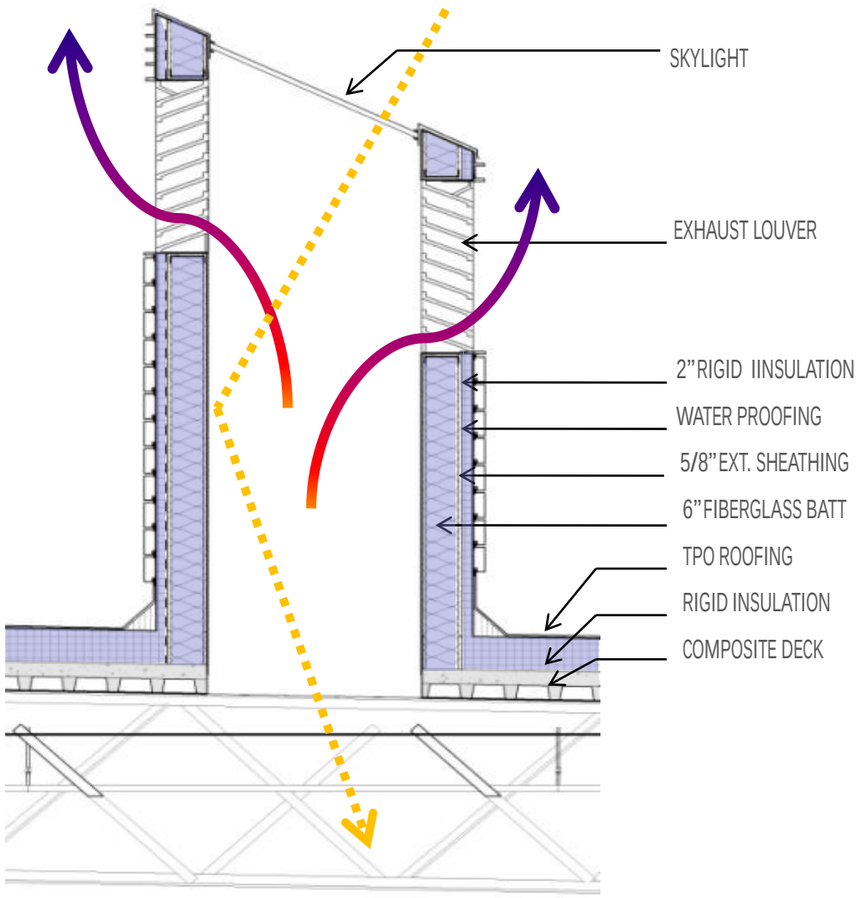
*22.9 kBTU/sf/yr under current model

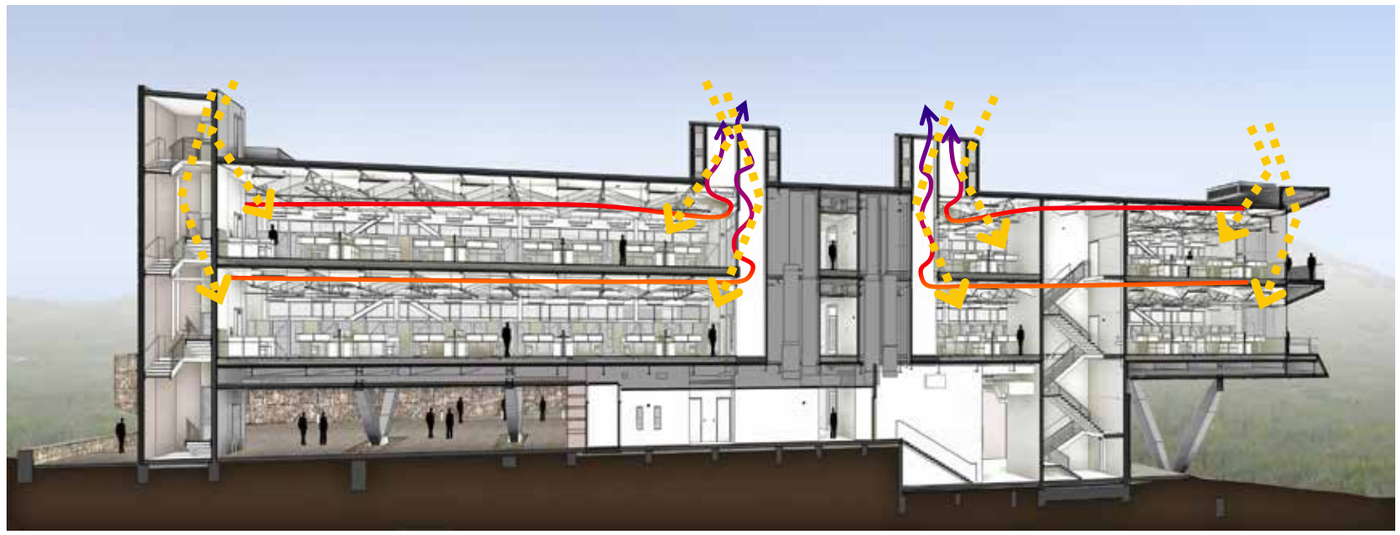


- *The Data Center that serves the ESIF office is located in a separate building and NREL wanted to assign 65 Watts continuous consumption per employee*
- ***26.7 kBtu's – 16.84 kBtu's (86% for Server and Equipment plug loads) = 9.9kBtu's left over to design to (current design accomplished in 6.6kBtu's)*** *(pumps, lights, fans, heating, HVAC)*
- *Natural ventilation has not been modeled*



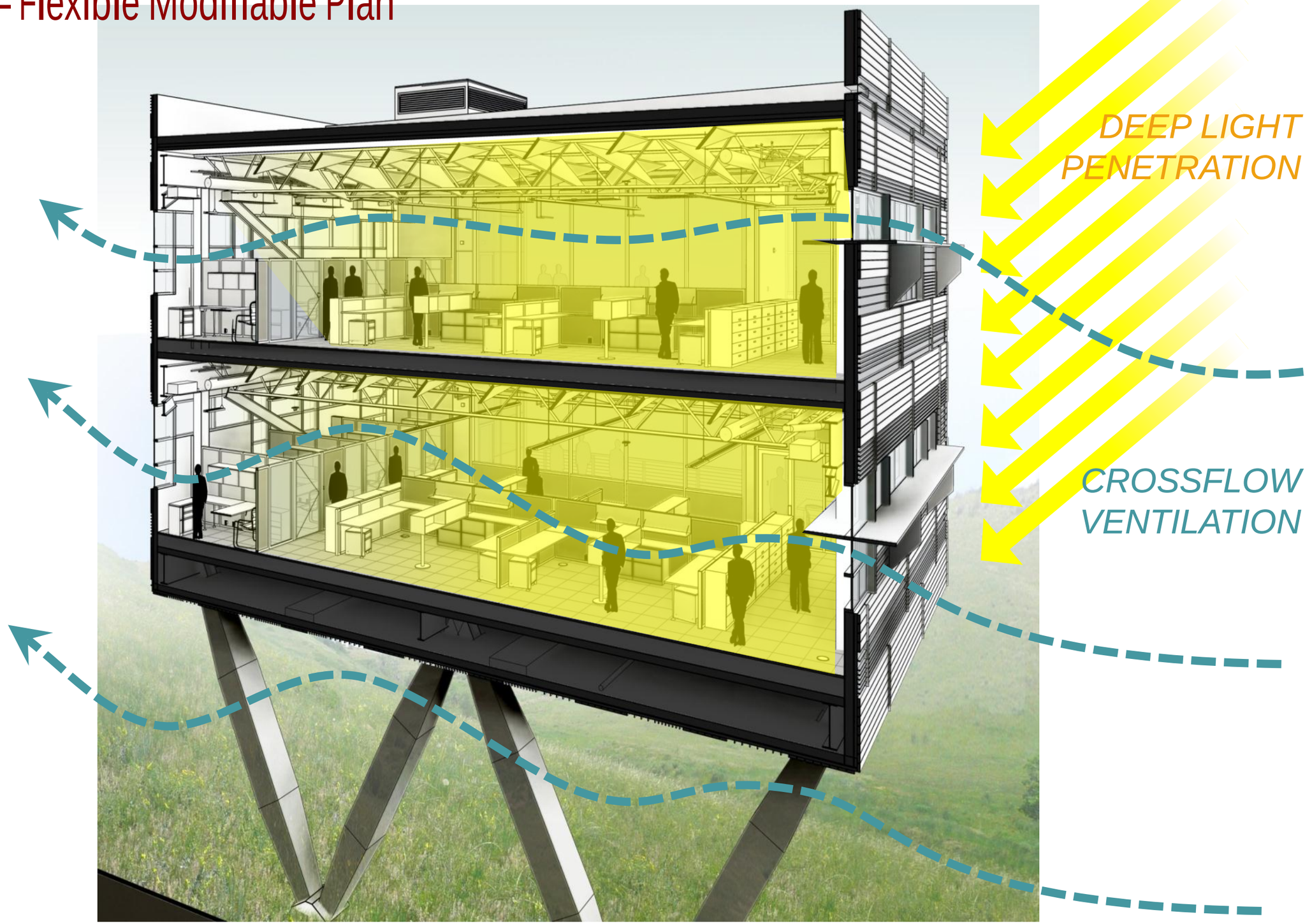
# Energy Reduction Strategies



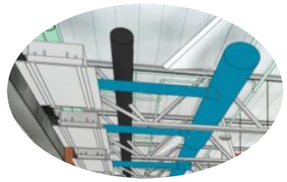
# Efficient Planning – Flexible Modifiable Plan

Shallow 60' office depth allows for cross ventilation and deep light penetration



# Office

## Floors 2 & 3 – Systems Integration



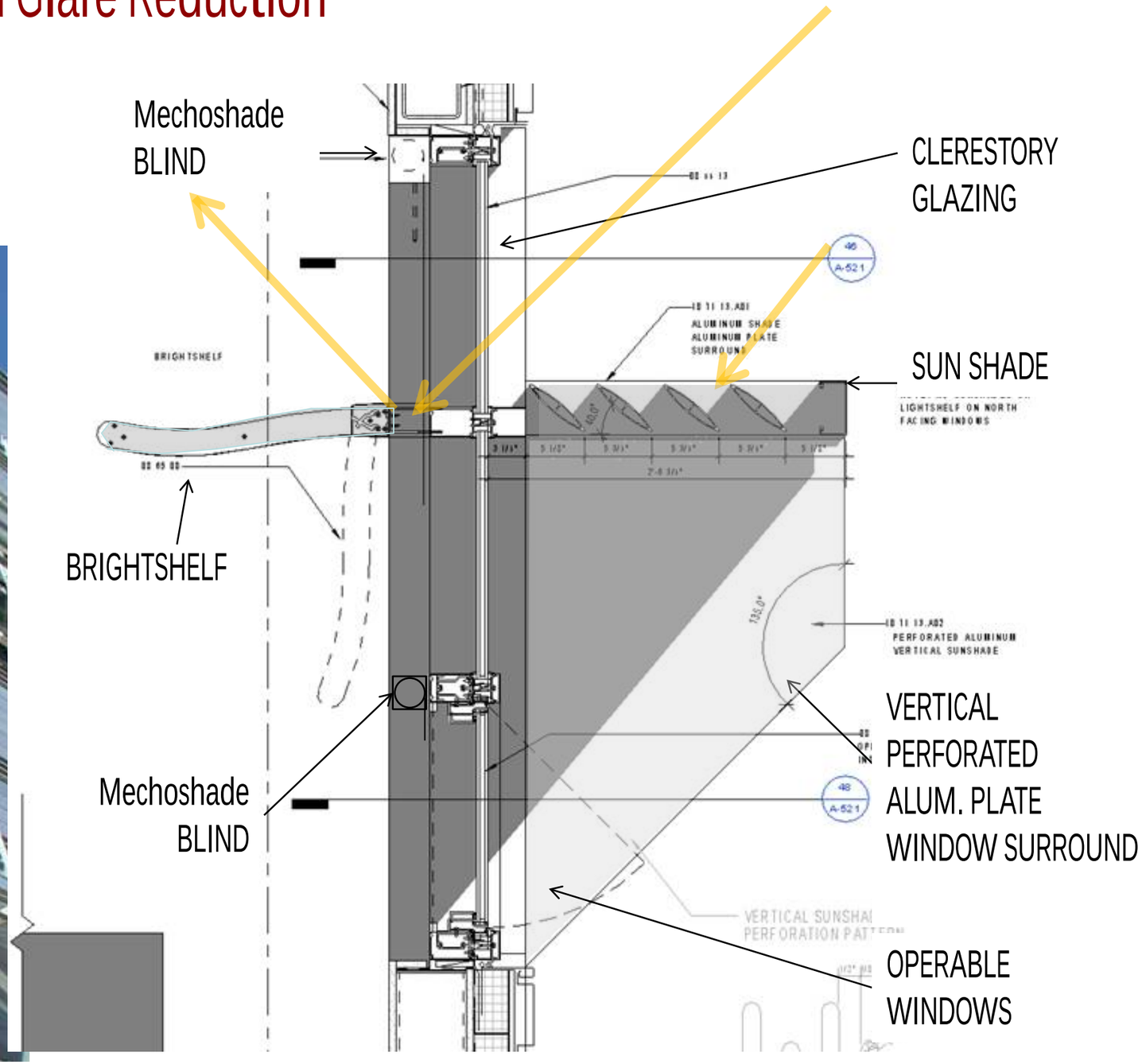
ACTIVE RADIANT, BEAM, HEATING & COOLING

SHADING, LIGHT SHELF

OPEN OFFICE

UNDER FLOOR AIR

# Intelligent Envelop – Tuned for Daylight and Glare Reduction

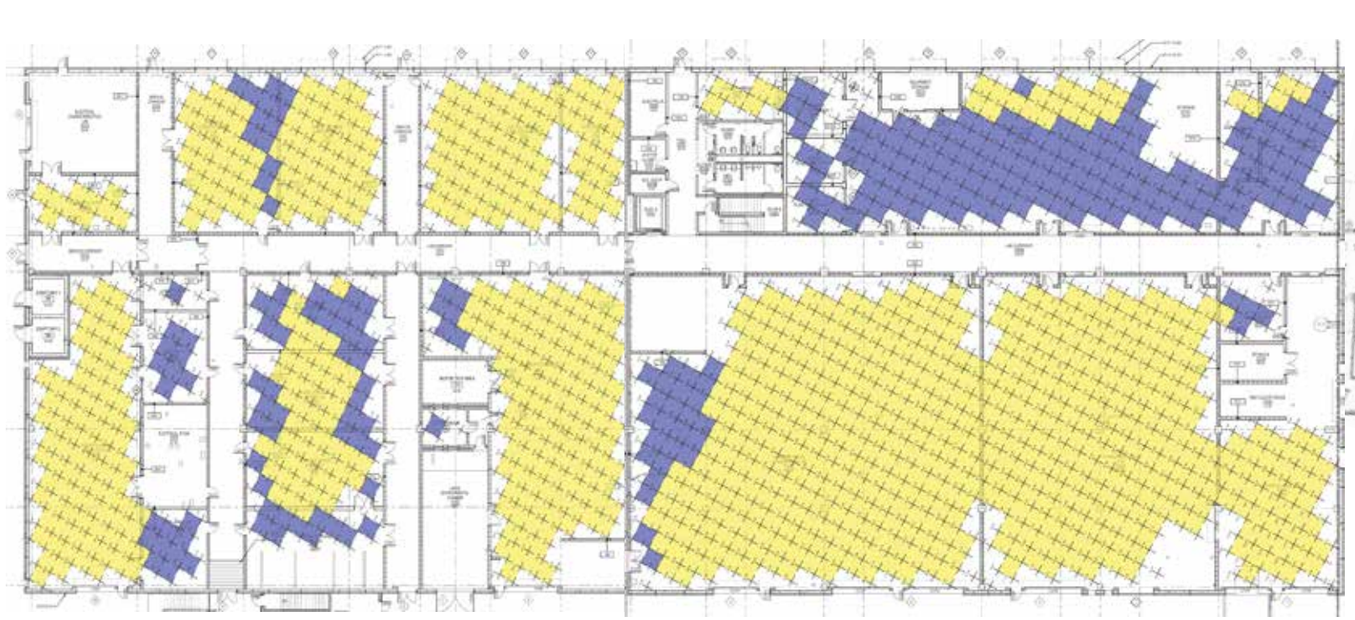


# Open Office

# Office Collaboration

# Daylighting Analysis

## LEED day lighting requirement: 75% of the regularly occupied area receiving 25 foot candles



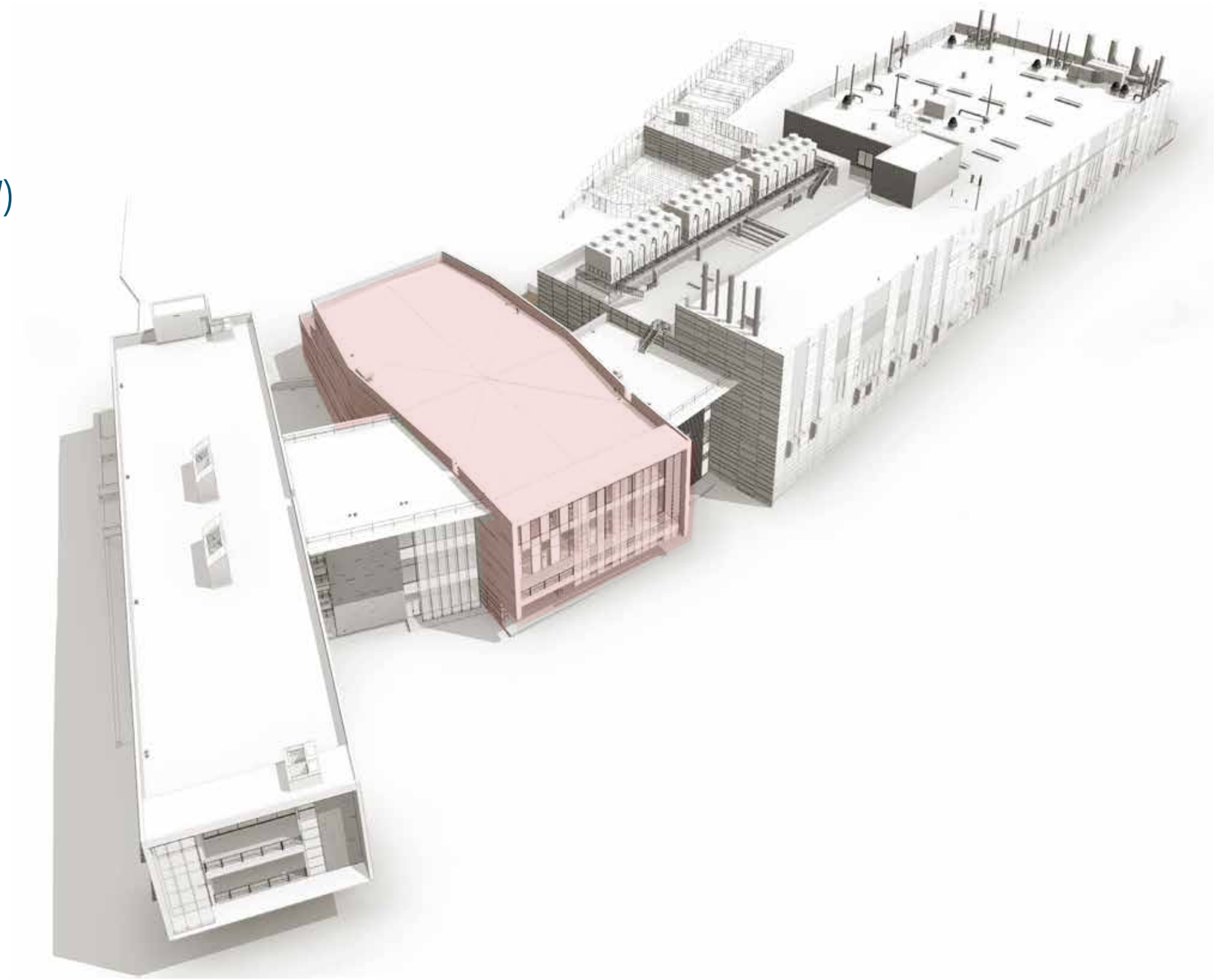
| | | |
|---|---|---|
| **High-Bay Lab Building** (Area A & B) | Regularly Occupied Spaces Area | 42596 |
| | Area Achieving EQc8.1 Requirements | 30316.4 |
| | % of Area Achieving EQc8.1 | 71.2% |
| **Data Center Building** (Area C) | Regularly Occupied Spaces Area | 5901 |
| | Area Achieving EQc8.1 Requirements | 5566.4 |
| | % of Area Achieving EQc8.1 | 94.3% |
| **Office Building** (Area D) | Regularly Occupied Spaces Area | 29424 |
| | Area Achieving EQc8.1 Requirements | 25628.2 |
| | % of Area Achieving EQc8.1 | 87.1% |
| **Project Totals** | Regularly Occupied Spaces Area | 77921 |
| | Area Achieving EQc8.1 Requirements | 61510.9 |
| | **% of Area Achieving EQc8.1** | **78.9%** |

# Data Center, Conferencing & Insight Center

# Section

# Data Center

- 2.5 MW – Day one capacity  (Utility $500K/yr/MW)
- 10 MW – Ultimate Capacity
- Initial 400 Teraflop
- No Vapor Compression for Cooling



# Data Center

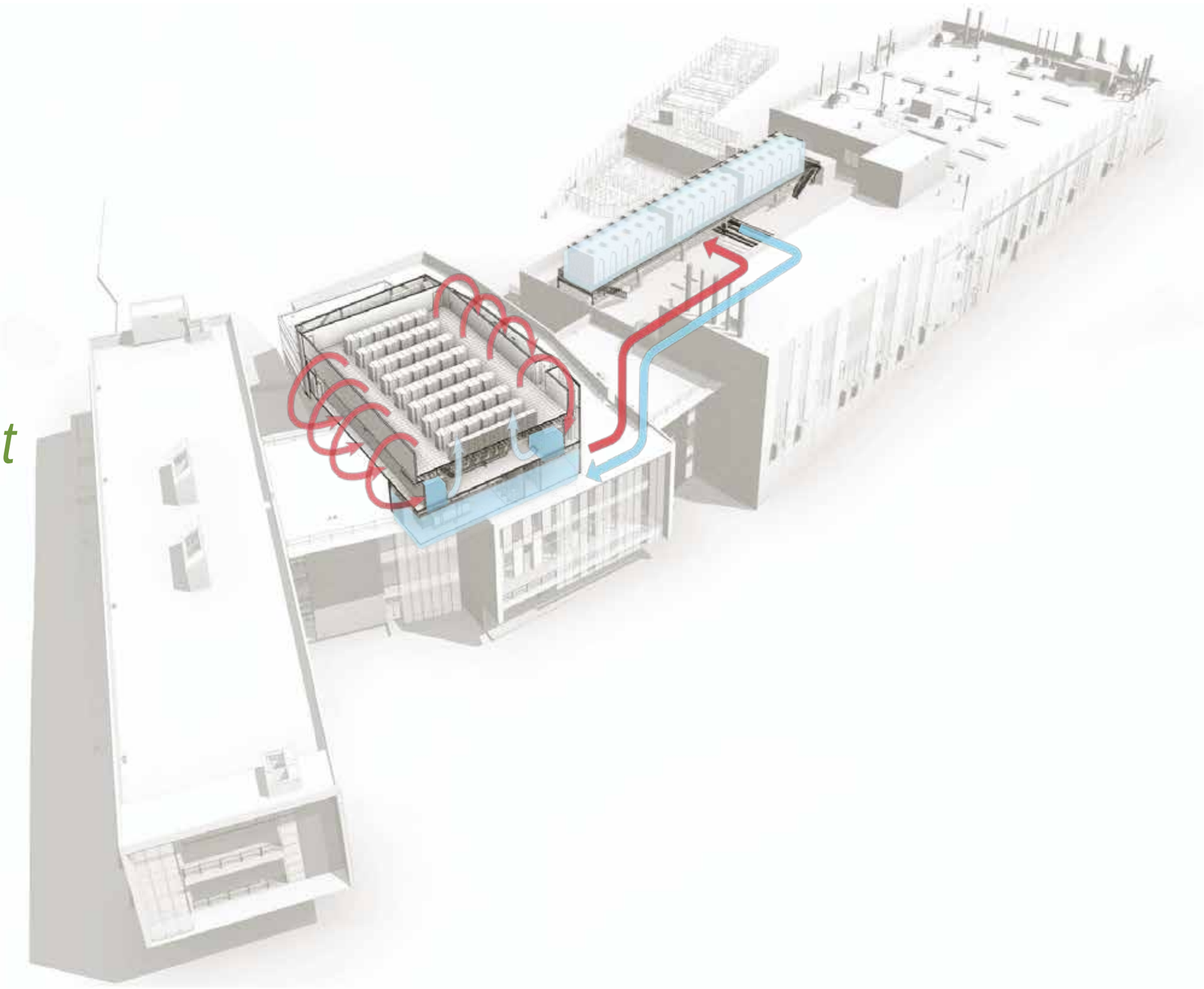
## Summer Cooling Mode

**PUE** – Power Utilization Efficiency

*Total Energy Used by Facility /*
*Energy used by Computing Equipment*

Typical Data Center = 1.5 – 2.0
NREL ESIF= 1.04

* **30%** more energy efficient than your typical "green" data center



# Data Center

## Winter Cooling Mode

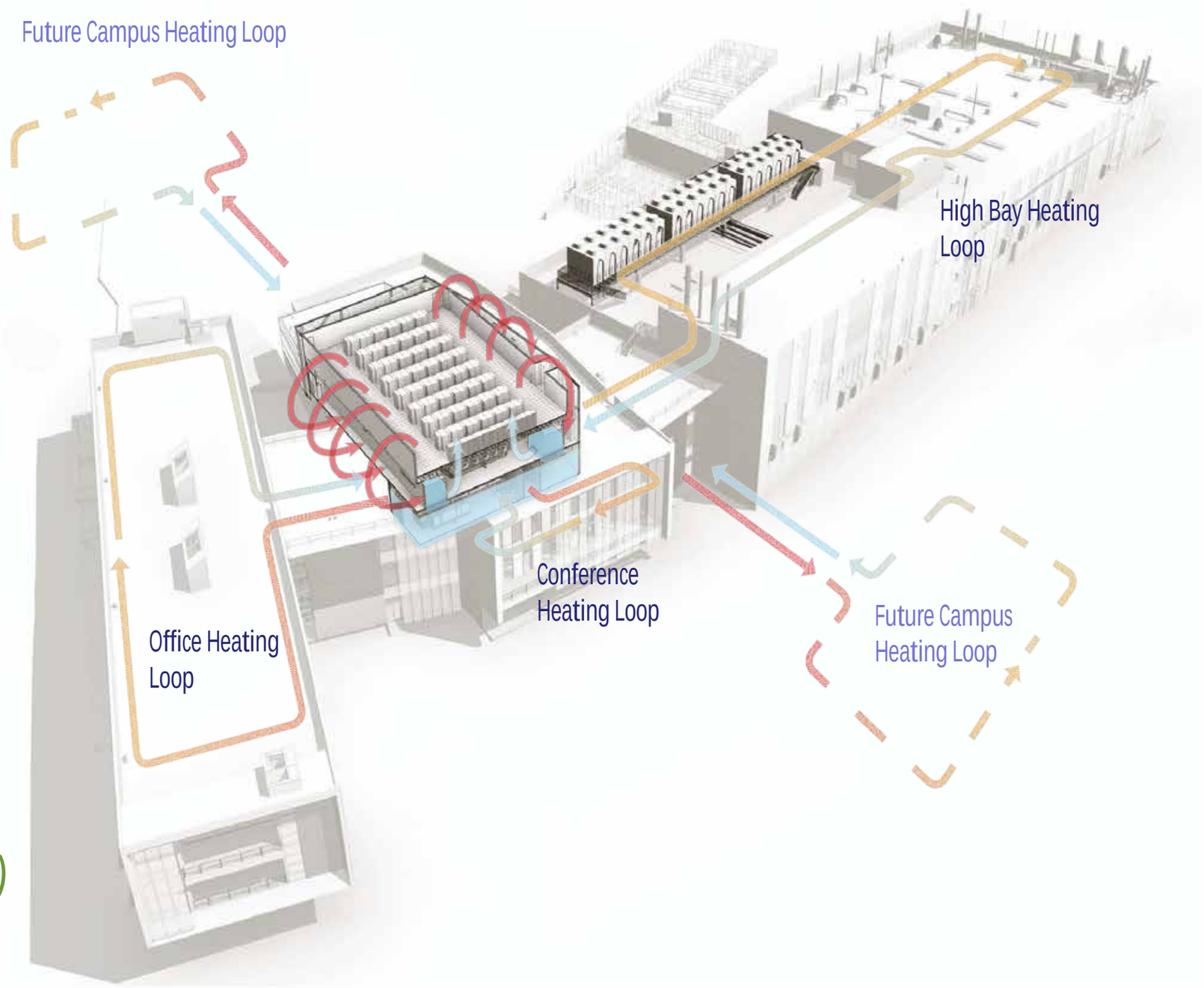
**EUE** – Energy Utilization Efficiency

*How efficient are we using the waste heat to heat the rest of the building?*

RFP Target = .9 *(use 10% of waste heat)*

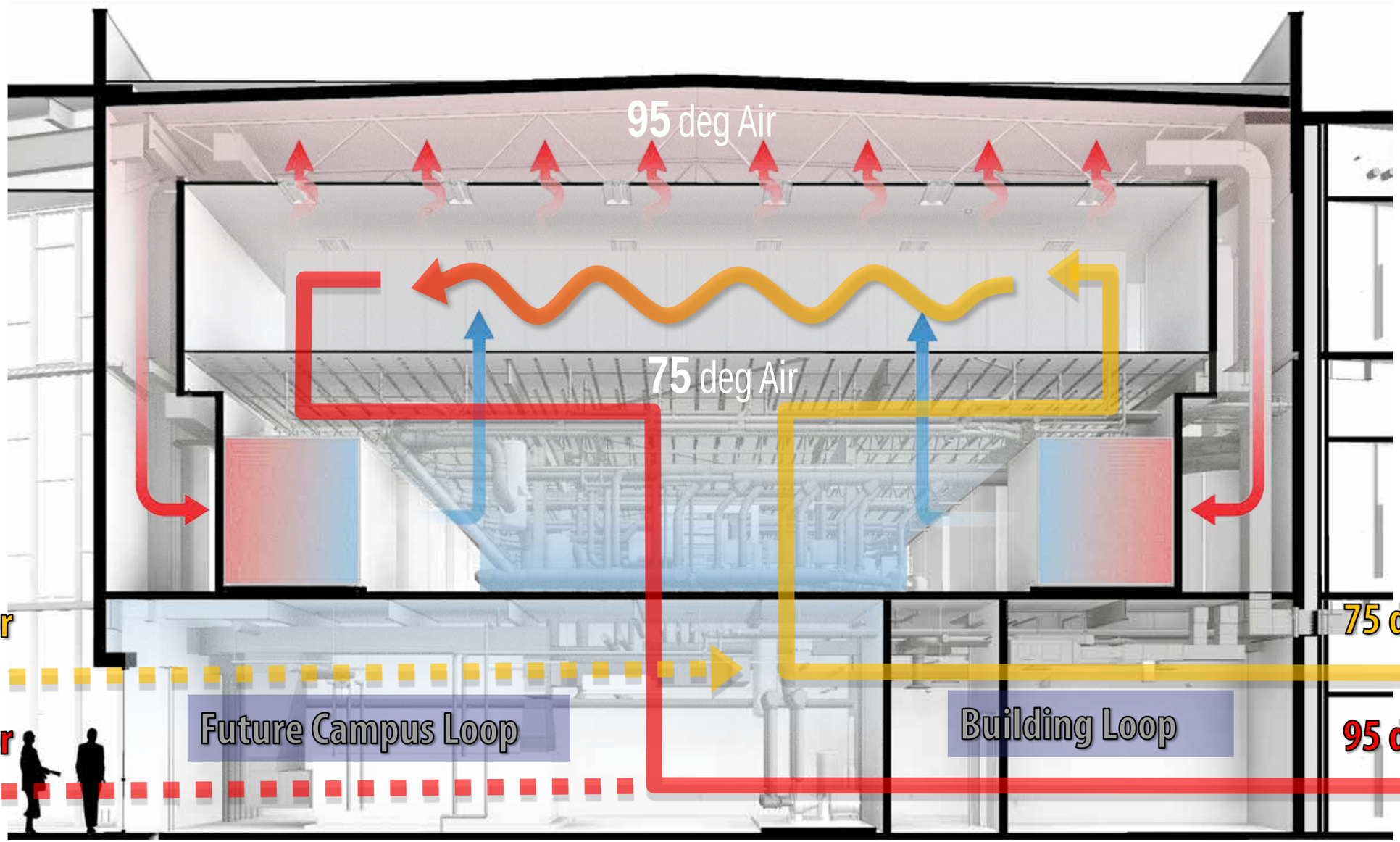
NREL ESIF= .7 *(we use 30% of waste heat)*

* We used **20%** more of the waste heat day one. *(more with future campus loops)*



# Data Center – Cooling Strategy

- Air Cooling for Legacy Equipment handles 10% of total Load
- Hydronic Cooling for High Performance Computers handles 90% of total load

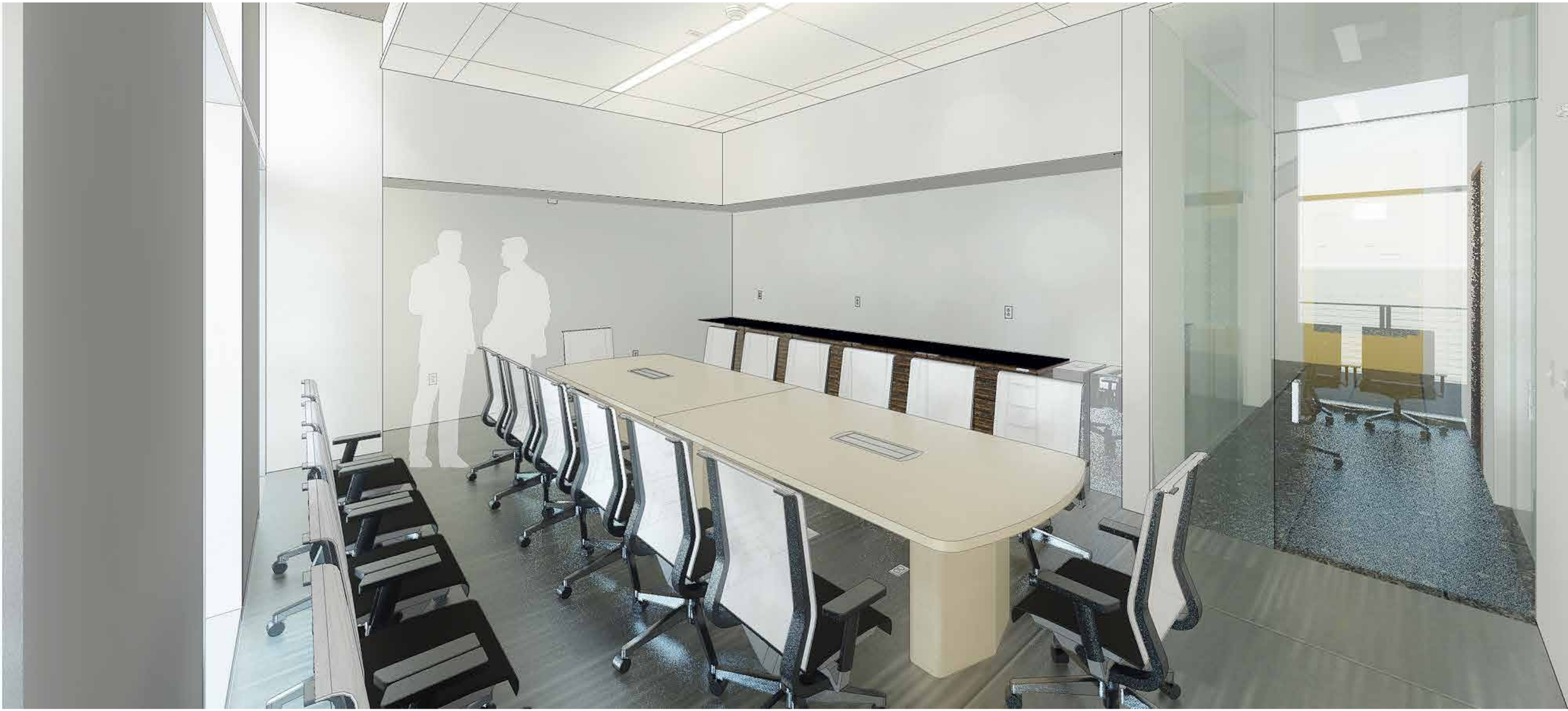


# Data Center

# Data Center on Display

# Conferencing & Insight Center

# Conference

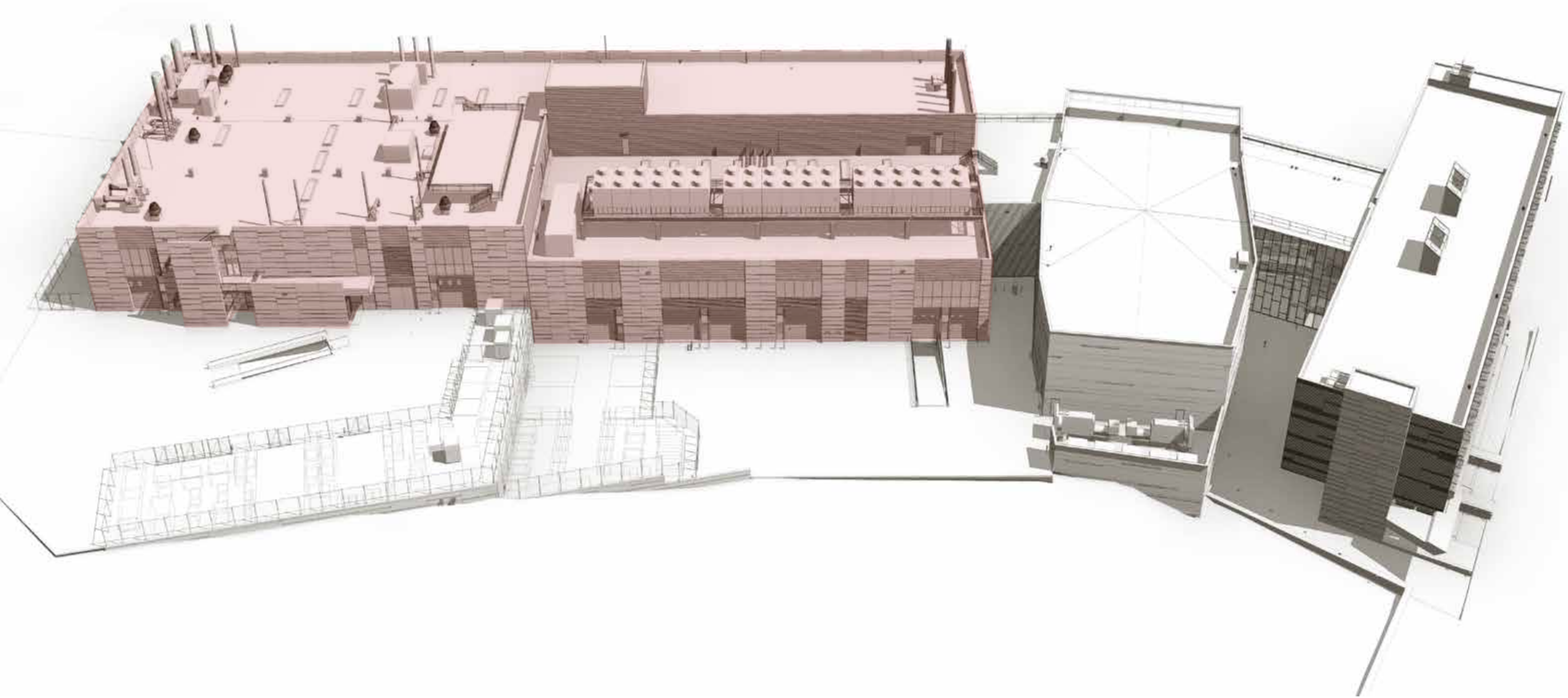


# Insight Center

# Visualization

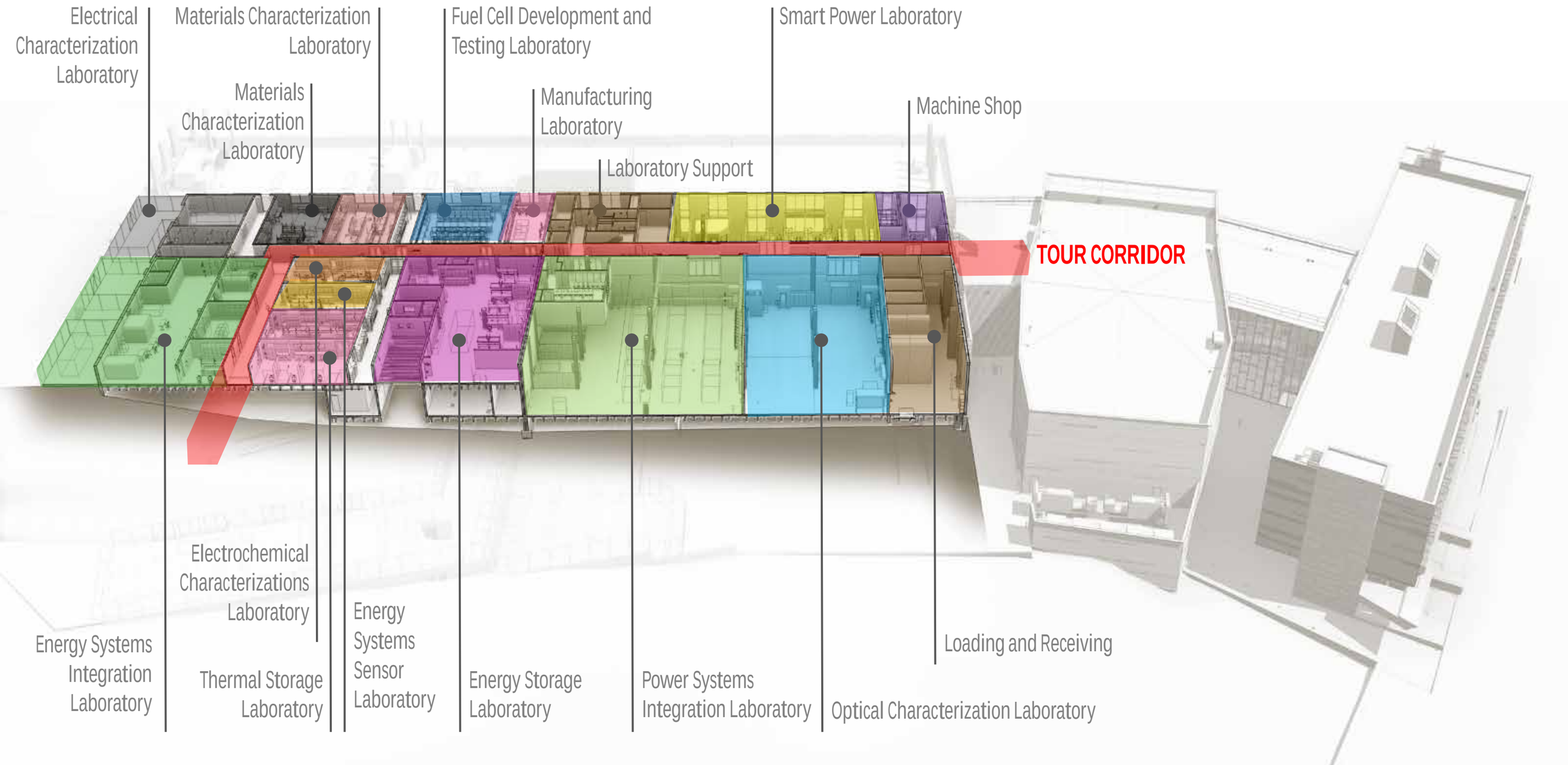
# High Bay Lab

# High Bay



# High Bay

# High Bay Testing Areas



# Power Systems Integration Laboratory

# Energy Storage Laboratory

# Material Characterization Laboratory

# Manufacturing Laboratory

REDB

# Isolated Testing

Electrical Characterization Laboratory

High Pressure Test

# Energy Systems Integration Laboratory

# Outdoor Testing

# Showcase

# Tour Corridor

# High Bay Laboratory Strategies

- Air handling units to provide direct / indirect evaporative cooling and humidification for minimum ventilation
- High efficiency, variable air volume hoods connected to a central laboratory exhaust system. System varies stack velocity based on wind speed and wind tunnel testing
- Heat rejection from data center utilized for space heating through the use of active chilled beams/ fan coil / VAV terminal heating coils depending on space type
- Research chilled water loop configured to reject cooling to HPCDC during testing periods

Questions?

# #NRELESIF

Kevin Brettmann
Director, Science & Technology, JE Dunn Construction, @jedunn

Adam Denmark, AIA, LEED AP BD+C
Principal, SmithGroupJJR, @Adam_SGJJR

JE DUNN CONSTRUCTION

SMITHGROUP JJR

National Renewable Energy Laboratory (NREL)
**Energy Systems Integration Facility**
Golden, Colorado