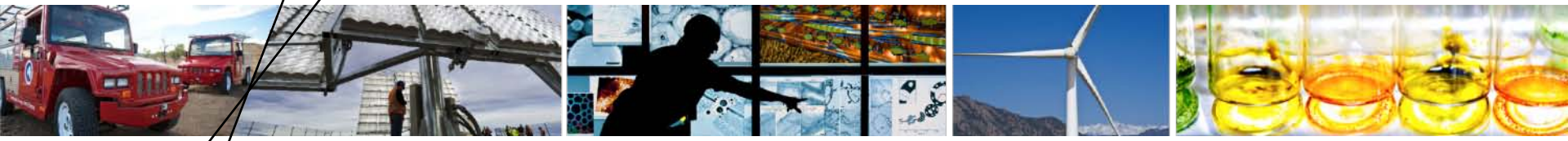
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Energy-Goal-Based Building Procurement:

Achieving 90% Energy Savings in a Parking Structure



Commercial Building Energy Alliance

Shanti Pless, NREL

Jennifer Scheib, NREL

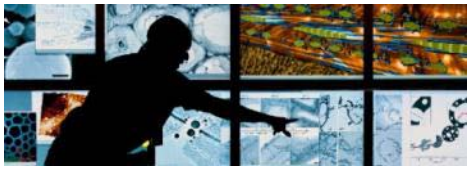
Phil Macey, AIA

August 8, 2012

Overview

- **Campus background**
- **Parking structure**
  - Objectives
  - Determining the energy goal
  - Design solution
  - Energy performance
- **Discussion about innovation and replication**
- **Resources for replication**

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NREL Campus Background

NREL Campus Background

- Pre-2007 construction:
  - Laboratories with offices
  - Infrastructure

2008 aerials, NREL PIX 15827, 16911

NREL Campus Background

- Post-2007 construction:
  - Offices (RSF)
  - Laboratory with office (ESIF)
  - Data centers (RSF and ESIF)
  - Full-service café
  - Site Entrance Building (SEB)
  - Infrastructure

Research Support Facility I (RSF I), NREL PIX 19548

Energy Systems Integration Facility (ESIF) rendering, courtesy Smith Group

NREL Campus Background

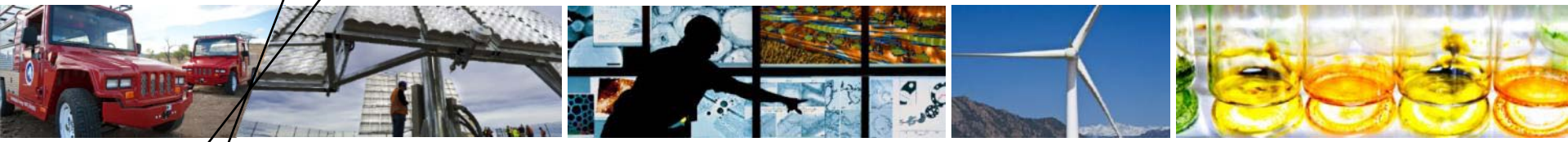
2012 aerial, Photo by Sincere/Duncan Studios courtesy of JE Dunn Construction

NREL Campus Background

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

- Procurement process attributes *post*-2007:
  - Design-build project delivery
  - Specific energy performance requirements in the Request for Proposal (RFP, also referred to as the contract)
    - RSF I, office example: 25 kBtu/ft^2/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

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



DOE/NREL Parking Structure

Parking Structure Project Overview

- Provides parking for full campus buildout
- $29.8 million (includes site entrance building)
- Built sustainably at no additional cost
- Part of RSF complex net zero energy boundary
- Best value selection
- Additional $1 million award fee for superior performance

Parking Structure Project Overview

November 2009 Integrated Project Team (IPT) formed
.
.
March 2010 Request for Qualifications (RFQ) issued
April 2010
May 2010
June 2010 RFP issued
July 2010 One-on-one proposal meetings held
August 2010 Kickoff meeting held with design-build team and IPT
September 2010 Phase I Notice to Proceed issued
October 2010
November 2010
December 2010 Design documents completion (general timeframe for multiple milestones)
January 2011
February 2011 Phase II Notice to Proceed issued
.
.
.
.
.
.
February 2012 Substantial completion

Parking Structure Objectives

“Mission Critical,” top tier RFP language

- 1,500 net additional parking spaces for automobiles
- Comply with NREL requirements
- ***Parking structure(s) maximize LEED points***
- Meet the budget and schedule
- Promote ease of mobility and campus circulation
- Integrate campus security

Parking Structure Objectives

"Highly Desirable," middle tier RFP language

- Minimize community impact
- 1,800 maximum parking spaces for automobiles
- Two-month early completion
- ***Achieve energy goal for parking structure (175 kBtu/space/yr)***
- Minimize structure height
- ***Maximize photovoltaic (PV) capacity capability***
- Life cycle cost efficiency (maximize)
- Shuttle stop is weather protected
- Promote carpooling and preferential high occupancy vehicle parking for a minimum 5% of spaces
- Incorporate recycling drop-off collection point
- Provide covered bicycle parking
- Provide industry-supported Electric Vehicle Supply Equipment (EVSE) for 2% of spaces immediately available on opening day
- Minimize operations and maintenance for snow and ice removal

Parking Structure Objectives

"If Possible," bottom tier RFP language

- Three-month early completion date
- Provide infrastructure support to expand the industry-supported EVSE to accommodate up to 20% of the spaces without upgrading or modifying the electricity distribution system
- Parking management technology
- Motorcycle parking

Determining the Energy Goal

Must a new energy goal be determined? If so, follow the first five steps before drafting the RFP:

1. Identify occupant types, tasks, and demand profiles
2. Estimate daylight (or passive strategy) savings potential
3. Select a best-in-class lighting power density (LPD) (or base load) from case studies (or tools)
4. Add energy use for best-in-class security systems, elevators, parasitic loads, etc.
5. Add energy or cost credits for preferred solutions
6. Present goal to proposing teams for review
7. Require that the energy goal be substantiated throughout design, construction, and occupancy

Determining the Energy Goal

Step 1. Identify occupant types and tasks

- Use lighting measurements from your own portfolio and IESNA resources
- NREL parking structure used 1 footcandle (fc) as a minimum horizontal illuminance requirement (higher daytime ramp and entrance values not used due to daylighting requirement)
- *Glare reduction language also included in the RFP*

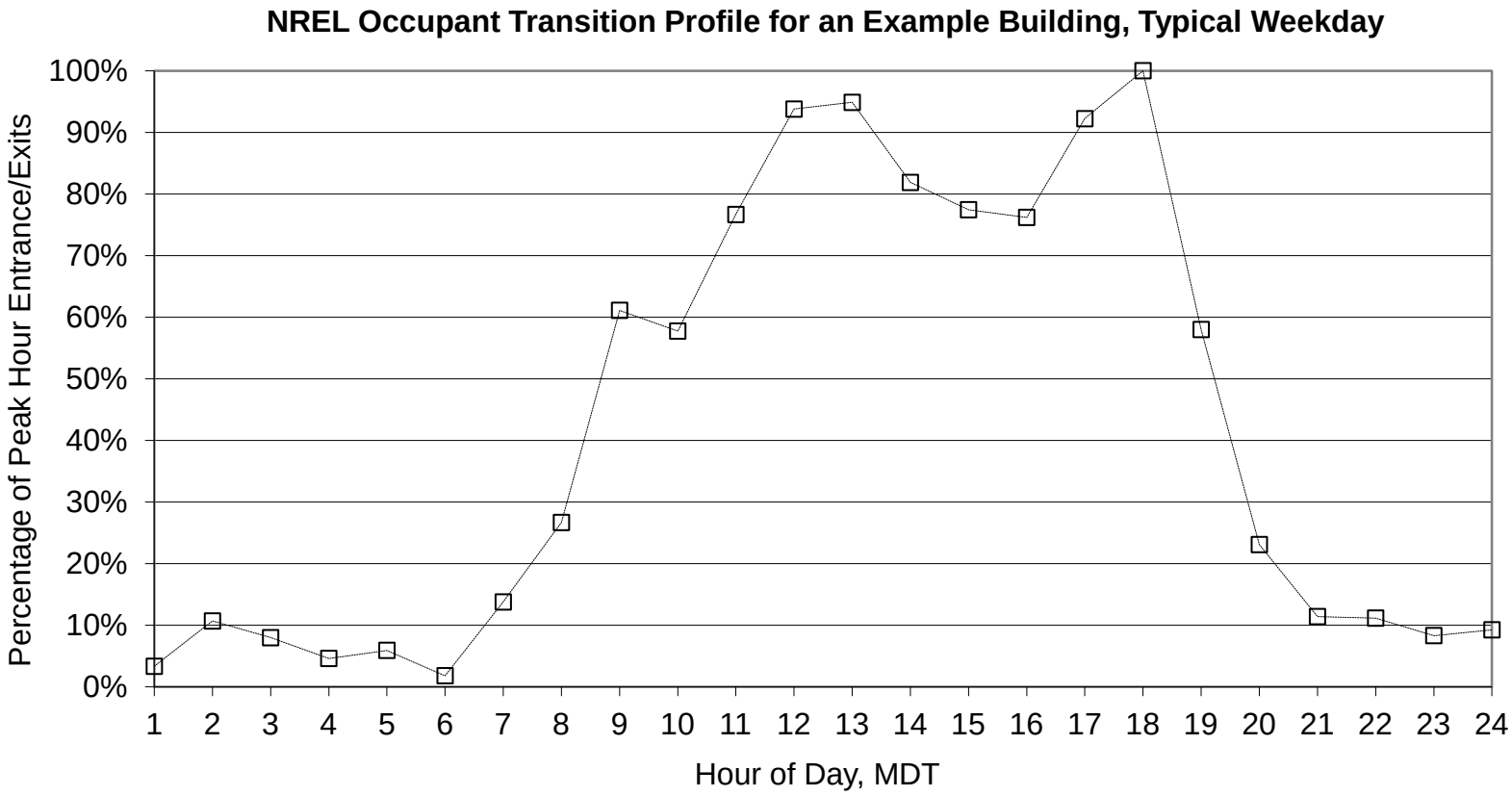
IESNA Lighting Handbook, Ninth Edition and CBEA High-Efficiency Parking Structure Specification v1.0 Recommendations (CBEA values are in parentheses where they differ from IESNA recommendations)

Area	Time	Minimum Horizontal Illuminance (fc)	Uniformity Ratio (maximum: minimum)	Minimum Vertical Illuminance (fc)
Basic	–	1.0	10:1 (7:1)	0.5
Ramps	Day	2.0	10:1	1.0
Ramps	Night	1.0	10:1	0.5
Entrance	Day	50.0	10:1	25.0
Entrance	Night	1.0	10:1	0.5
Stairs	–	2.0 (N/A)	10:1 (N/A)	0.1 (N/A)

Determining the Energy Goal

Step 1 (cont.) Identify occupant demand profiles

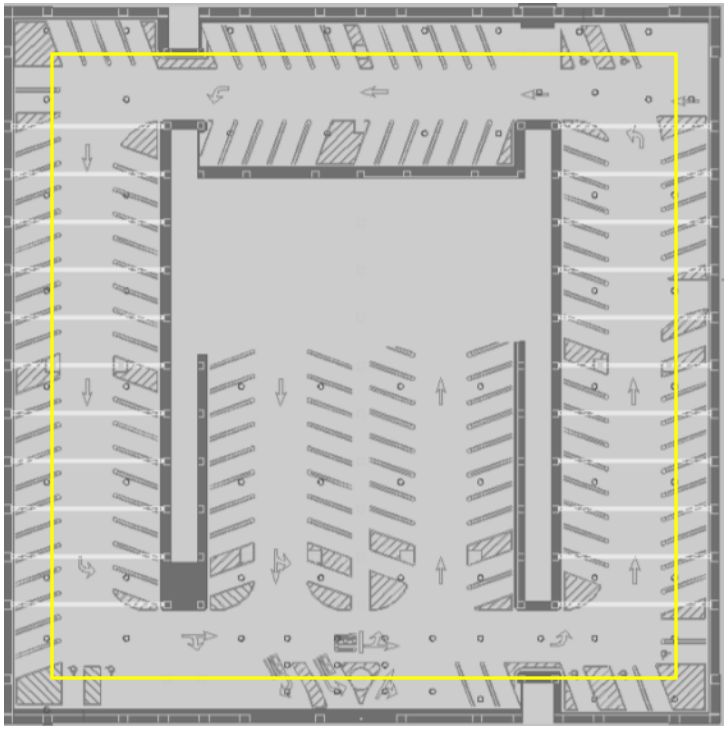
- Use security, door alarm data, or light/occupancy logger data for estimates
- NREL parking structure used a 25% nighttime use assumption to calculate goals



Determining the Energy Goal

Step 2. Estimate daylight savings potential

- Use case studies or modeling tools such as OpenStudio for daylight estimates
- NREL parking structure used a 25% daytime use assumption to calculate goals



Sample California parking structure, courtesy PNNL

	Sunny Climate Annual Average Illuminance (fc) at Floor												
250	776	151	134	112	72	76	56	71	80	48	60	94	377
230	481	69	86	35	28	27	28	29	25	26	31	46	119
210	453	51	69	64	14	12	13	16	10	12	23	63	102
190	150	44	24	58	6	7	6	6	4	8	48	64	331
170	425	94	17	9	7	4	5	5	4	7	49	71	339
150	740	97	68	7	8	2	5	2	6	6	52	41	347
130	743	94	68	8	4	5	5	5	2	7	43	67	353
110	746	90	64	56	5	4	2	2	4	4	47	70	346
90	744	97	65	58	4	5	4	2	2	7	47	32	337
70	744	103	73	11	14	9	8	1	1	6	49	35	113
50	488	115	110	24	70	36	76	2	1	1	60	124	129
30	789	166	105	134	64	74	107	111	71	100	55	91	446
10	1195	593	543	542	249	680	665	612	567	196	549	589	495
(ft)	10	30	50	70	90	110	130	150	170	190	210	230	250

Determining the Energy Goal

Step 3. Select an LPD

- Assess your own portfolio if possible
- Use case studies or simulation to explore state-of-the art lighting options
- NREL parking structure used 0.05 W/ft^2 to calculate goals

LPD and Achievable Illuminance Comparison

Resource	LPD (W/ft^2)	Average Illuminance (fc)	Typical Uniformity Ratio (maximum:minimum)
Lowest LPD of reviewed literature and calculations	0.05	≤ 1.5	<4:1
CBEA High-Efficiency Parking Structure Lighting Specification range with maximum LPD allowance	0.05–0.18	1.5–5	7:1
ASHRAE Standard 90.1-2007 maximum LPD allowance	0.3	≥ 5	10:1

Determining the Energy Goal

Step 4. Add energy use for security systems, elevators, parasitic loads, etc.

- Approximately 20 kBtu/space/yr controls allowance
- Excluded loads from the energy goal include power for recharging stations and intermittent plug loads such as those incurred by power washing structure surfaces

Step 5. Add energy or cost credits for preferred solutions

- Encourage average to small parking space size:
  - 8.5 ft x 19.5 ft parking space used to present goal per space
  - Transition area = 1½ times parking space area

NREL parking structure energy goal: *175 kBtu/space/yr*

Step 6. Present goal to proposing teams for review

- Proposal discussion indicated that the energy goal could be met and energy use close to 150 kBtu/space/yr might be possible

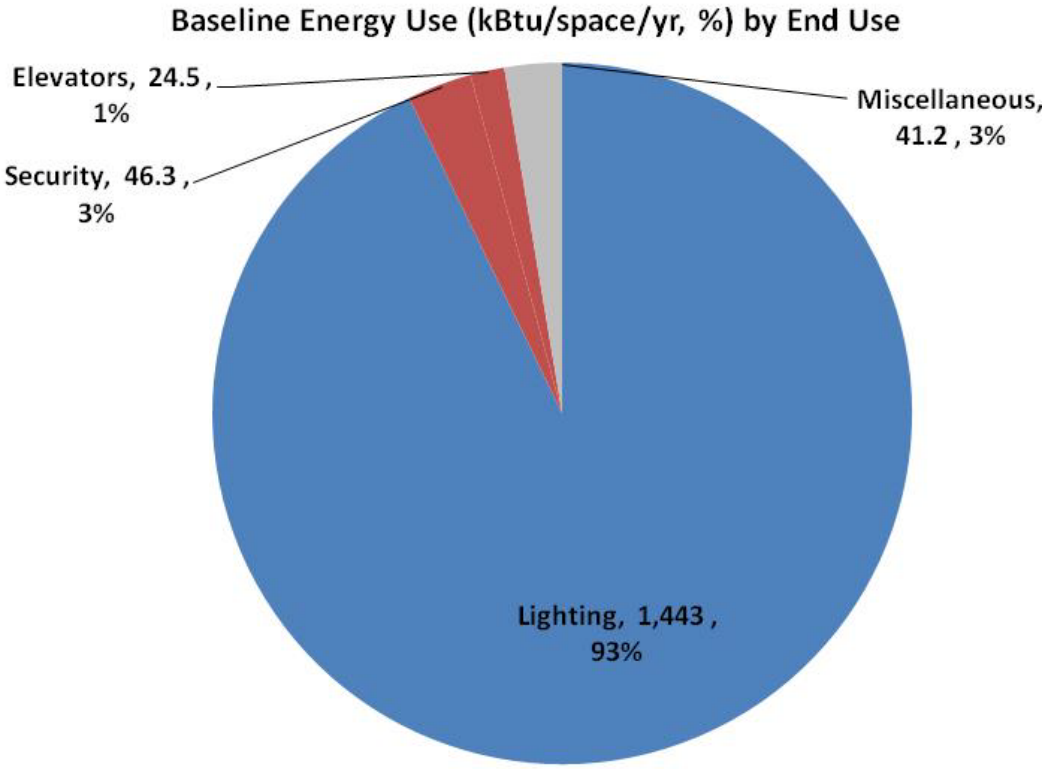
Step 7. Require that the energy goal be substantiated

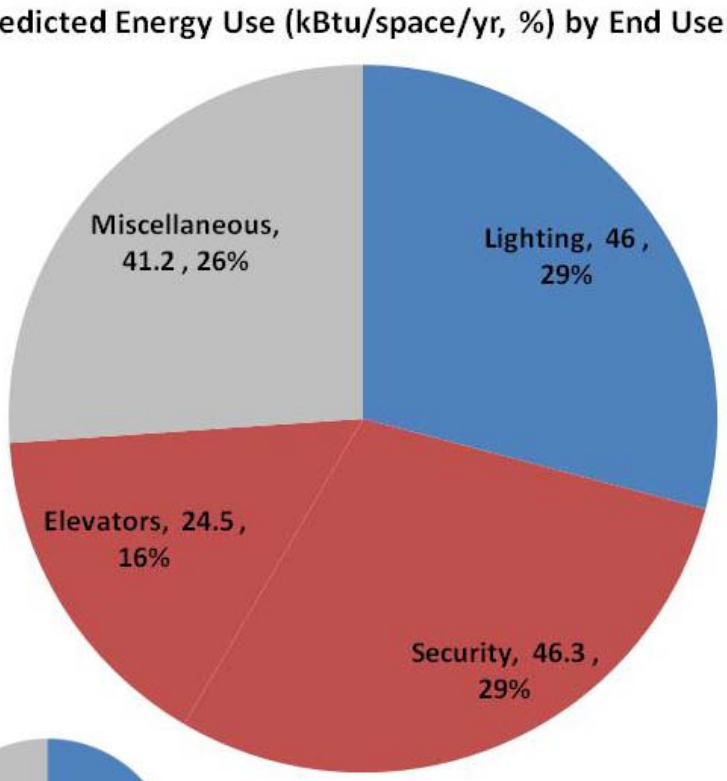
- Daylight reduction proxy was given as a minimum of 1 fc on a winter, overcast afternoon
- CBEA specification given to design engineers for electric lighting calculation parameters
- Submetering requirements

Design Solution—Metrics

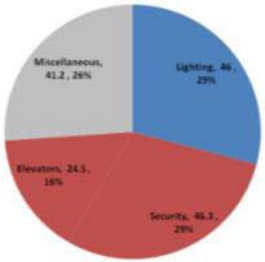
- **Parking Spaces**
  - 1,806 total spaces
  - 90 preferred spaces for carpooling and vanpooling, 90 preferred spaces for low-emitting vehicles, 36 electric vehicle charging stations
- **Cost**
  - $14,172 per parking space
  - $15,500 to $24,500 for typical parking space in Denver area
- **Renewable Energy**
  - 1.13 MW PV (net zero energy for RSF complex)
- **Energy Performance**
  - 158 kBtu/space/yr, designed
  - 90% energy reduction versus ASHRAE Standard 90.1-2007

Design Solution—Metrics





Predicted Energy Use Relative Size
(compared to baseline energy use)



Calculations performed by ME Group

Design Solution—Structure

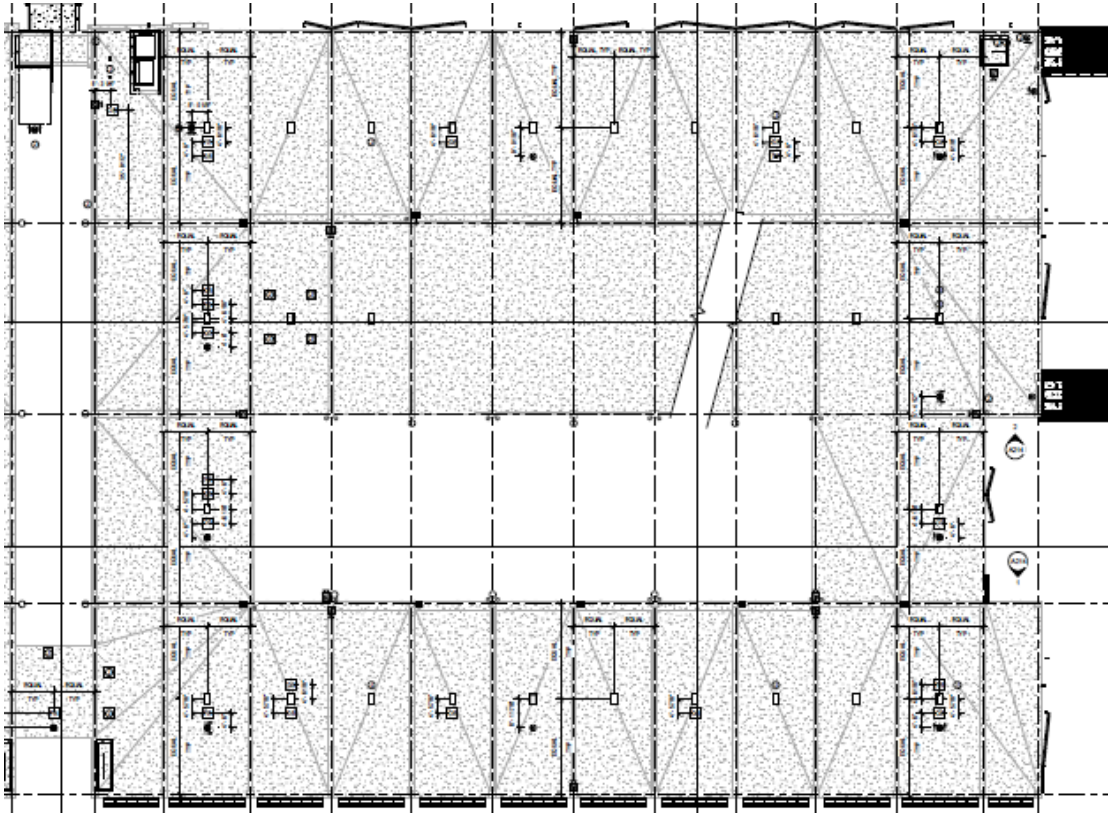
Southwest perspective rendering, RNL

Design Solution—Structure

Plan:

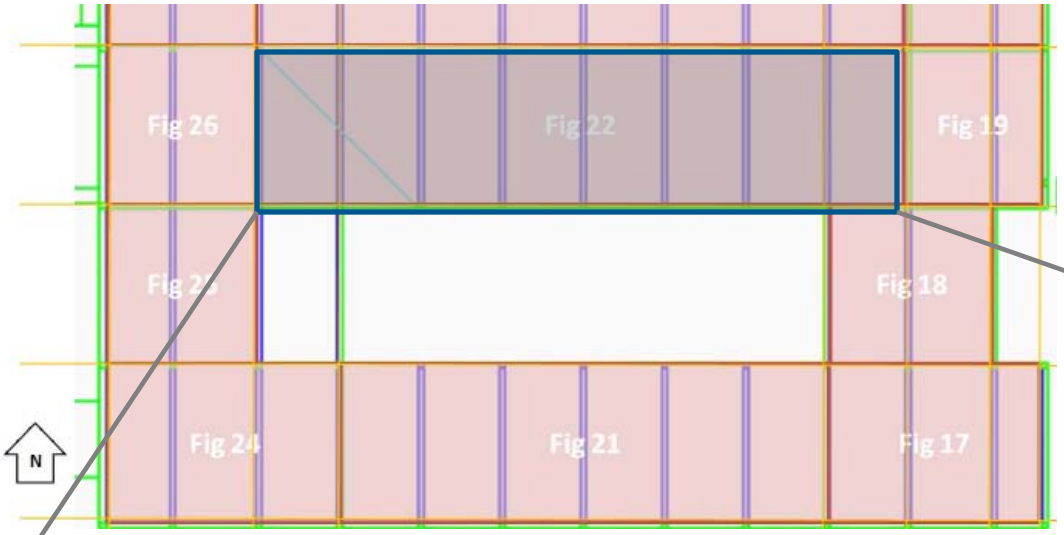
- Cast-in-place, post-tensioned base structure with steel-framed canopy
- PV-ready
- 60-ft wide light wells
- 60-ft bay depth

Light well perspective, Jennifer Scheib, NREL

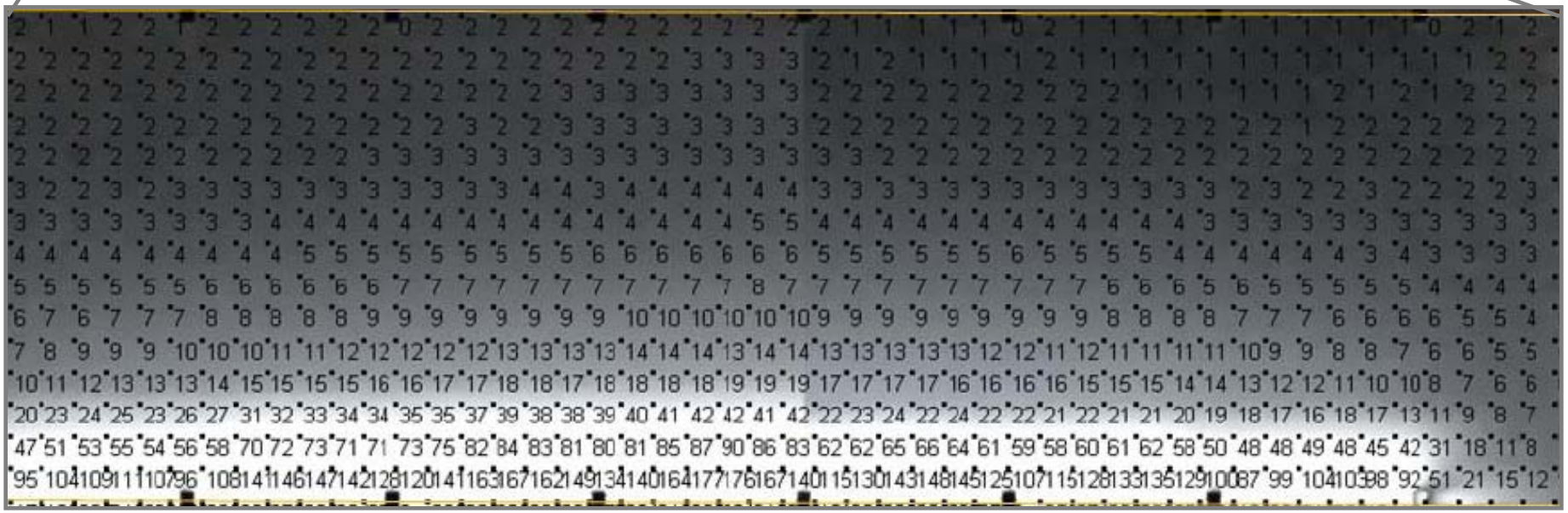


Second floor, east reflected ceiling plan, RNL

Design Solution—Structure



Calculations performed by Ambient Energy



Daylight levels in footcandles on February 4 at 2:00 p.m. under overcast sky conditions.

Design Solution—Structure

Elevation:

- No sheer walls
- Upturned beams
- Glass stair enclosures
- PV on south façade

Southeast perspective, Dennis Schroeder, NREL

Design Solution—Structure

Elevation: Cable barriers

Atrium stair, Dennis Schroeder, NREL

Design Solution—Structure

Elevation: Aluminum perforated panels

North perspective rendering, RNL

North perspective, Dennis Schroeder, NREL

Design Solution—Structure

Elevation:

Aluminum perforated panels optimized by daylight model

- 40% openness
- North, east, and west positioning

Top floor PV roof, Jennifer Scheib, NREL

Design Solution—Structure

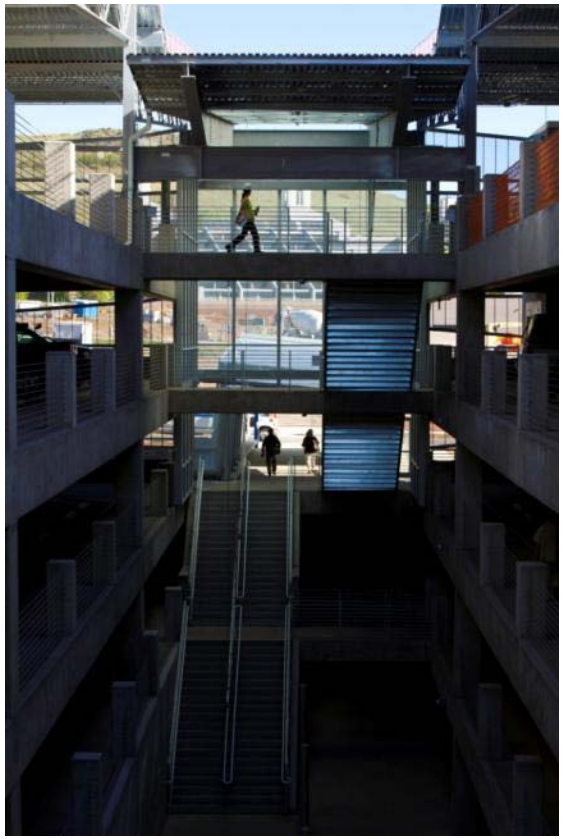
Interiors:

- Light concrete but no paint on ceiling or columns
- Slab and beam versus flat slab

Interior perspective, Jennifer Scheib, NREL

Design Solution—Structure

Interiors: Atrium staircase leading to bus shelter



Atrium and bus shelter, Dennis Schroeder, NREL

Design Solution—Systems

- **Electric lighting**
  - Light-emitting diode (LED) fixtures
  - Lighting controls
- **Security equipment**
  - Cameras
  - Gates
  - Public announcement speakers
  - Fire alarm controls
- **Miscellaneous**
  - Emergency phones
  - Equipment room fans and heaters
  - Heat trace
  - Parking management counter and signs
- **Two elevators**
  - Traction type
  - LED fixtures

Parking management and car charging equipment, Dennis Schroeder, NREL

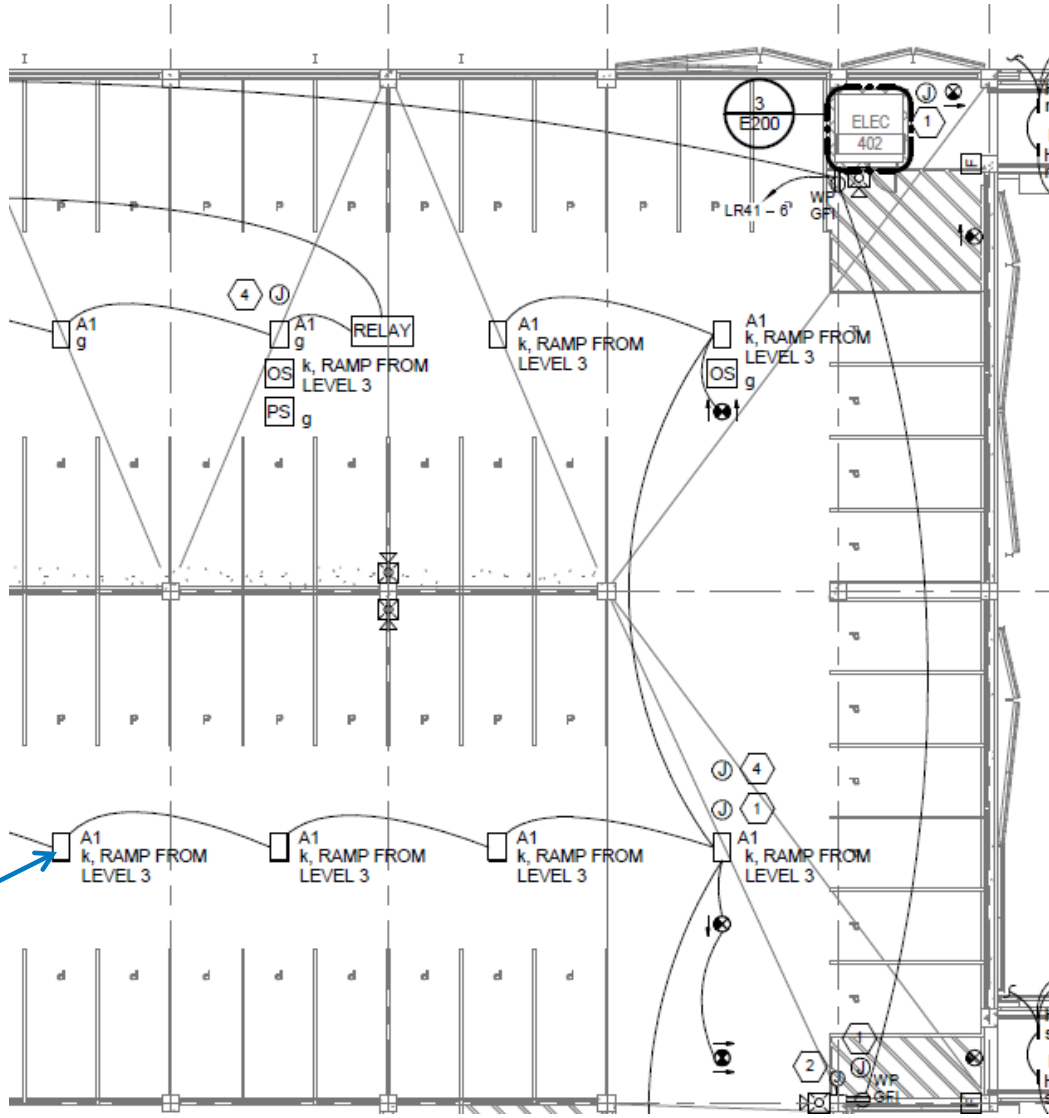
Design Solution—Systems

- **0.05 W/ft² LPD**

  CBEA specification was used for reference when reviewing lighting fixture submittals

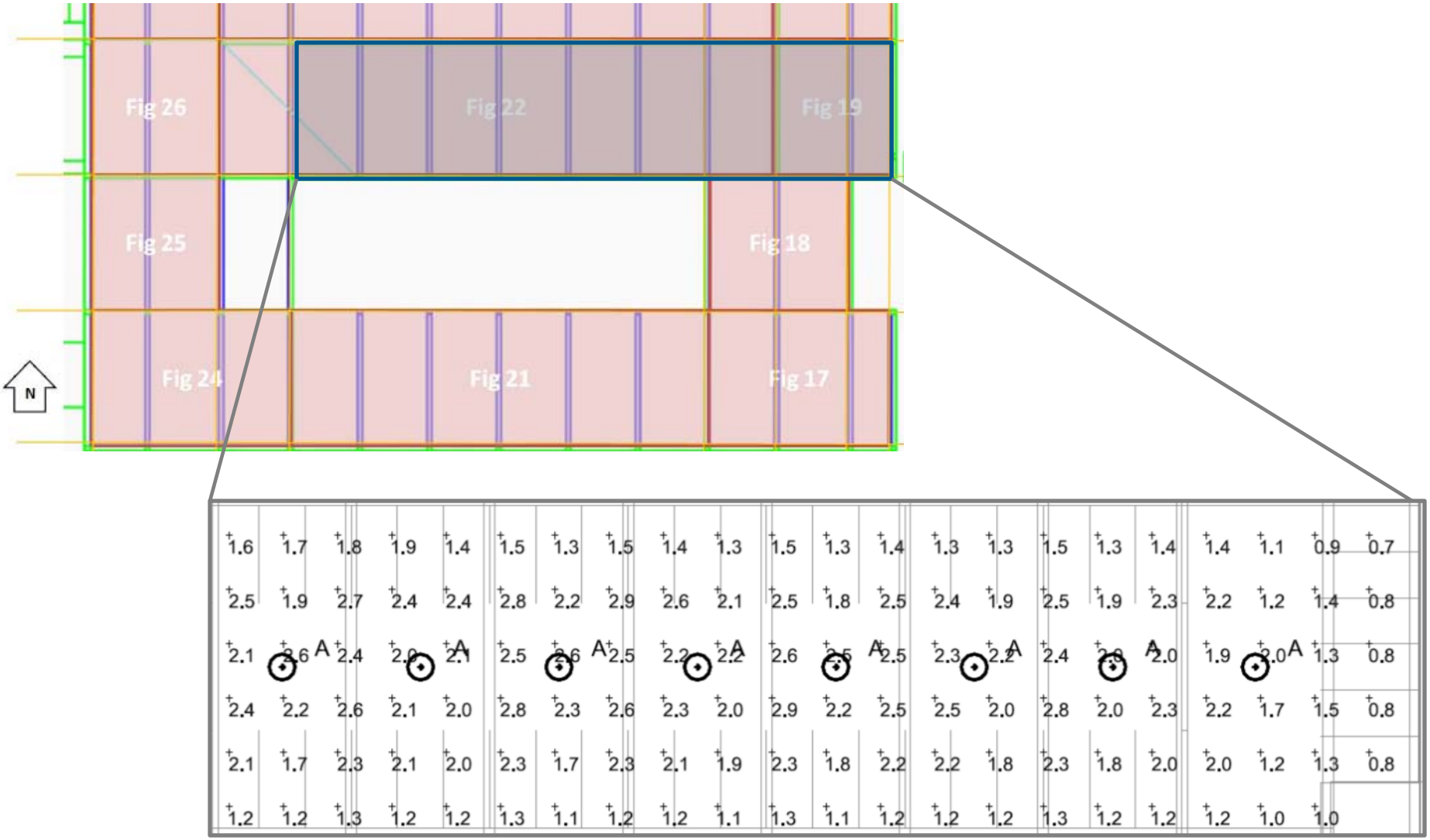
- **Lights are only on when needed**
  - Occupancy sensors (OS)
  - Photocells (PS)

LED fixture, Jennifer Scheib, NREL



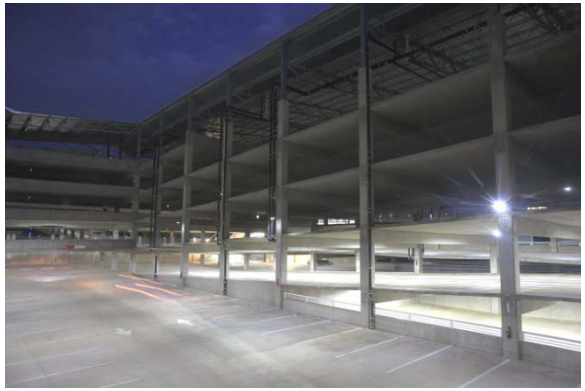
Lighting plan, courtesy ME Group and RNL

Design Solution—Systems



Lighting calculations performed by ME Group, plans courtesy Ambient Energy and RNL

Design Solution—Systems






Light well images, Dennis Schroeder, NREL

Design Solution—Systems

Light well, Dennis Schroeder, NREL

Design Solution—Systems

Light well, Dennis Schroeder, NREL

Design Solution—Systems

Light well, Dennis Schroeder, NREL

Design Solution—Systems

Light well, Dennis Schroeder, NREL

Design Solution—Systems

Light well, Dennis Schroeder, NREL

Design Solution—Systems

Light well, Dennis Schroeder, NREL

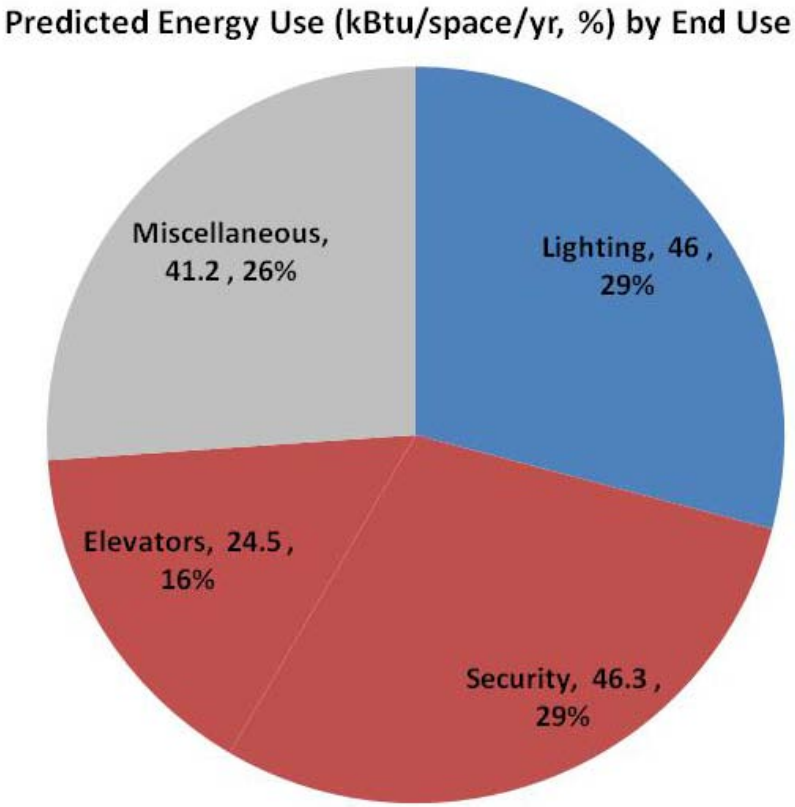
Energy Performance (preliminary, not validated)

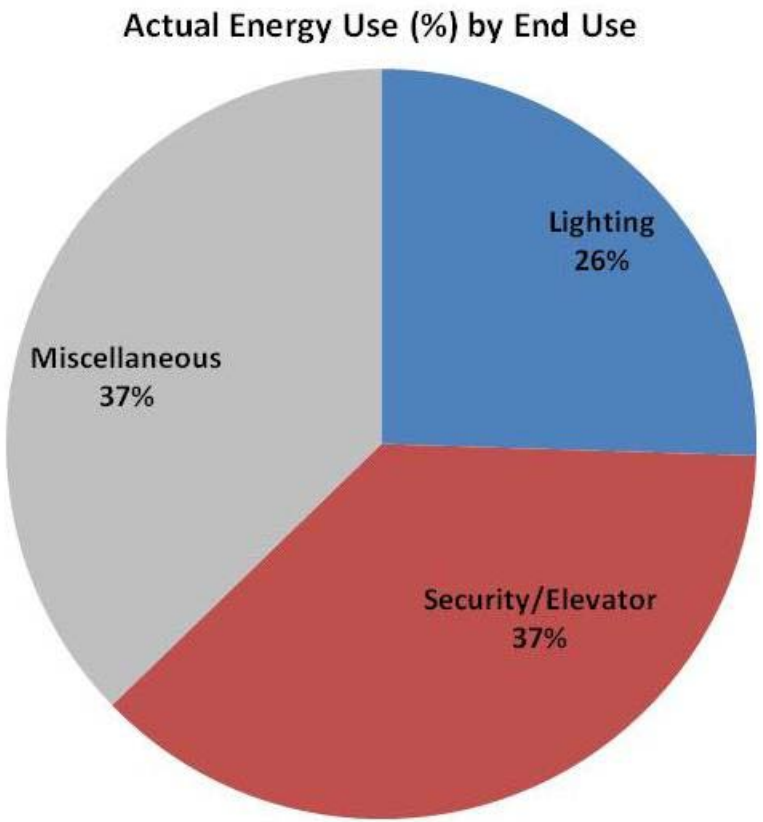
Power quality meter (energy) data from July 7, 2012, through July 23, 2012

- 107 kBtu/space/yr with no change in use
- Use will increase with:
  - Less daylight, resulting in more lighting use
  - Cold weather, resulting in use of heat trace and equipment heaters (miscellaneous)
  - Cold weather, resulting in use of camera heaters (security)
  - Cold weather, possibly resulting in more elevator use (icy stair conditions)

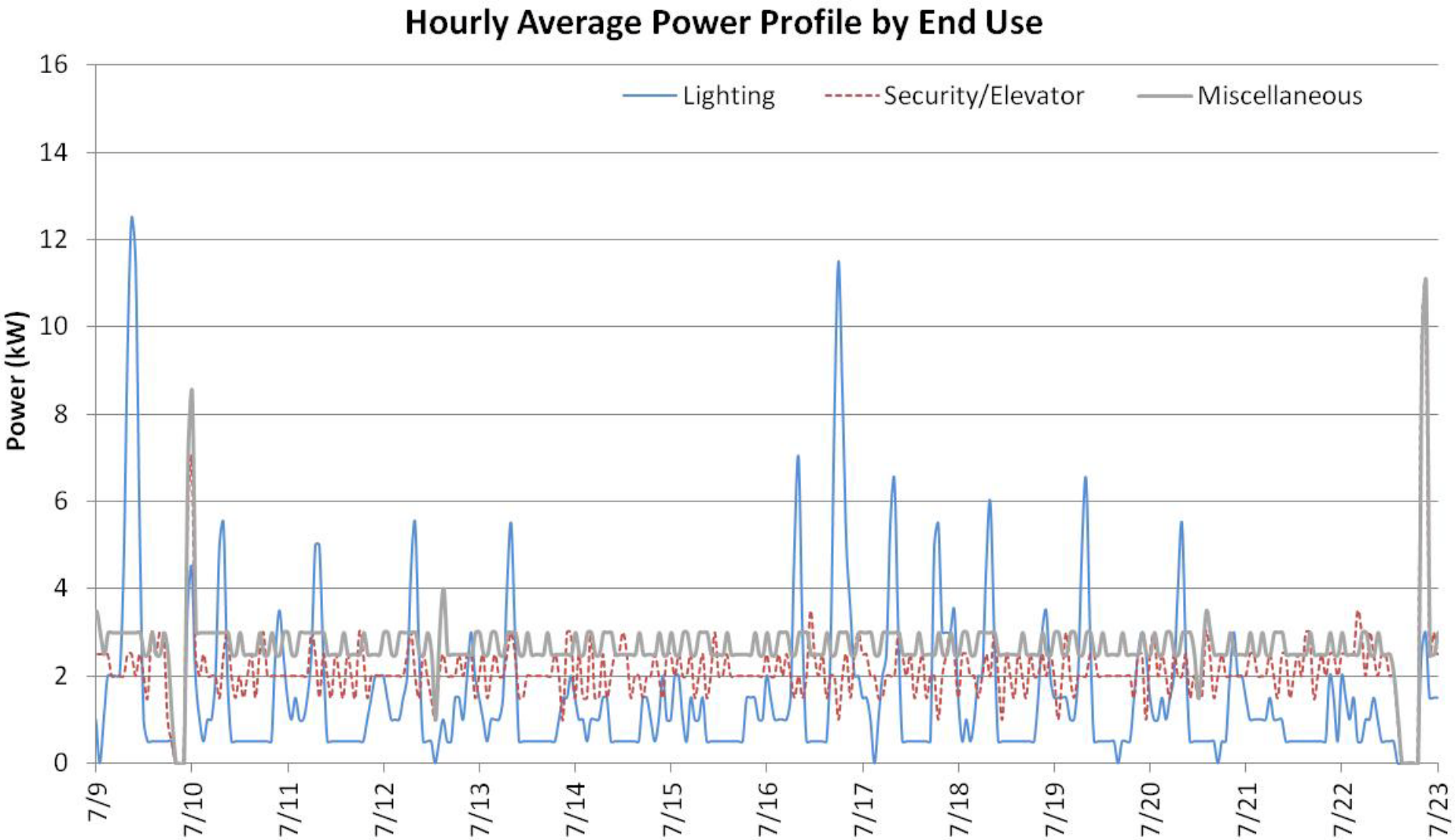
Energy Performance (preliminary, not validated)

Predicted versus power quality meter (energy) data from July 7, 2012, through July 23, 2012

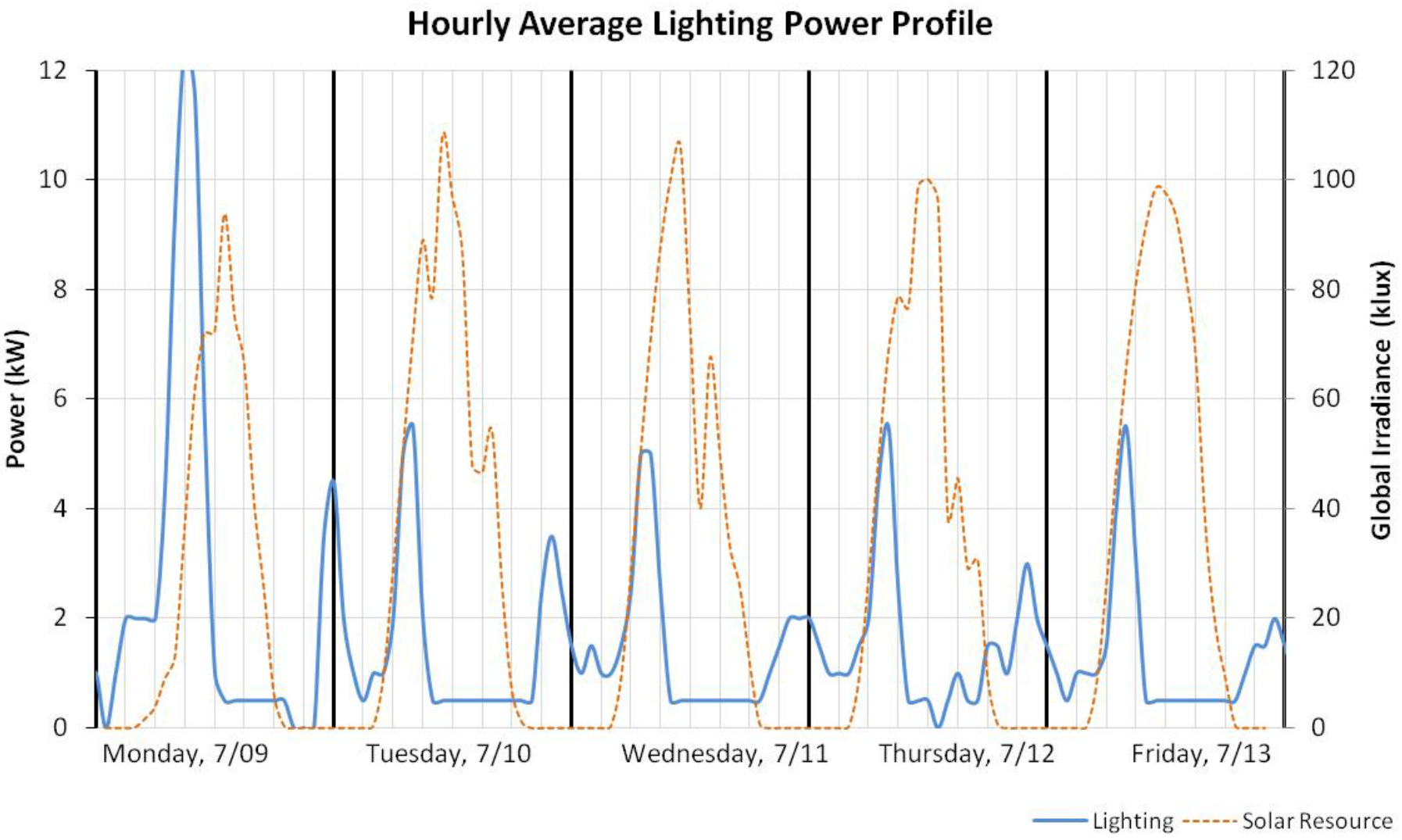




Energy Performance (preliminary, not validated)



Energy Performance (preliminary, not validated)



Discussion About Innovation and Replication

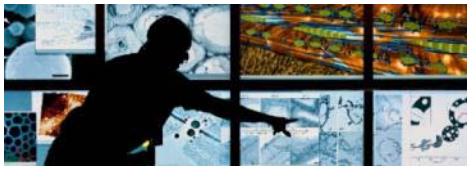
- **Process innovation**
  - Use performance-based procurement (energy goal with performance incentives)
  - Require integrated design with energy modeling, starting in the predesign phase, to maximize efficiency feature early
- **Design innovation**
  - Focus on structure first (structure type, perimeter configuration, bay width, structure depth, finishes, colors, percent fly ash)
  - Result in a low LPD with good nighttime cutoff
  - Implement a lighting control scheme that improves occupant experience in terms of aesthetics and safety
  - Reduce need or time of use for elevators, heat trace, ventilation, miscellaneous loads
- **Result:** Cost-competitive, energy-efficient, *beautiful* garage with carefully considered neighborhood interface

Resources

- How-to Guide for Energy Performance-Based Procurement: (publication expected fall 2012)
- Research Support Facility RFP and other resources: http://www.nrel.gov/sustainable_nrel/rsf.html
- Low-Energy Parking Structure Design Guide: (publication expected summer 2012)
- CBEA High-Efficiency Parking Structure Lighting Specification: http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/creea_parking_structure_spec.pdf
- CBEA Lighting Energy Efficiency in Parking (LEEP) Campaign

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Thank you for your time.

Questions?

Shanti Pless: shanti.pless@nrel.gov

Jennifer Scheib: jennifer.scheib@nrel.gov

Phil Macey: pmaceyaia@gmail.com