NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Army Dining and Maintenance Facilities: Study Results

Energy Efficient Technologies For Buildings and Communities

Rois Langner

January 26, 2011

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.

EPAct 2005

"The buildings shall be designed to achieve energy consumption levels that are at least 30 percent below the levels established in the version of the ASHRAE Standard or the International Energy Conservation Code, as appropriate"

EISA 2007

"The buildings shall be designed so that the fossil fuel-generated energy consumption of the buildings is reduced, as compared with such energy consumption by a similar building in fiscal year 2003 (as measured by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey data from the Energy Information Agency), by the percentage specified in the following table:

"Fiscal Year Percentage Reduction

2010 55
2015 65
2020 80
2025 90
2030 100

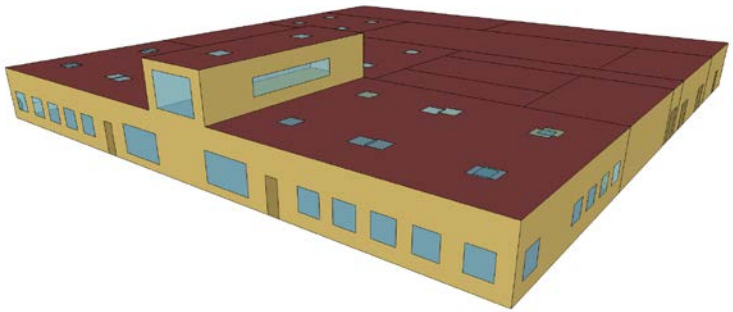
EISA 2007

1. Reduce energy consumption
    1. Explore energy efficiency measures (EEMs)
    2. Choose EEMs with highest energy savings

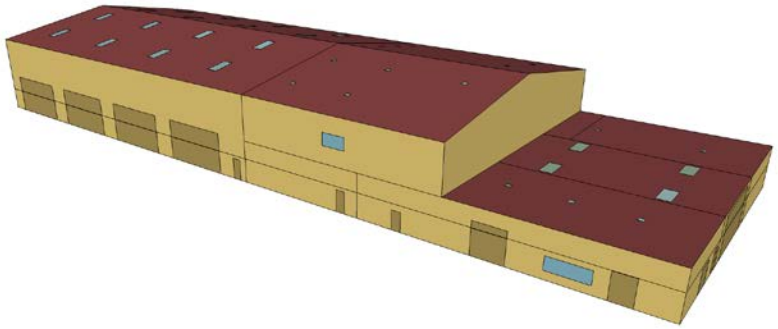
2. Source Energy
    1. Conversion factors:
       Electricity: 11.4 kBtu/kWh
       Gas: 1.047 kBtu/kBtu
    2. Identify renewable energy sources

Building Types and Climate Zones

Dining Facility (DFAC)



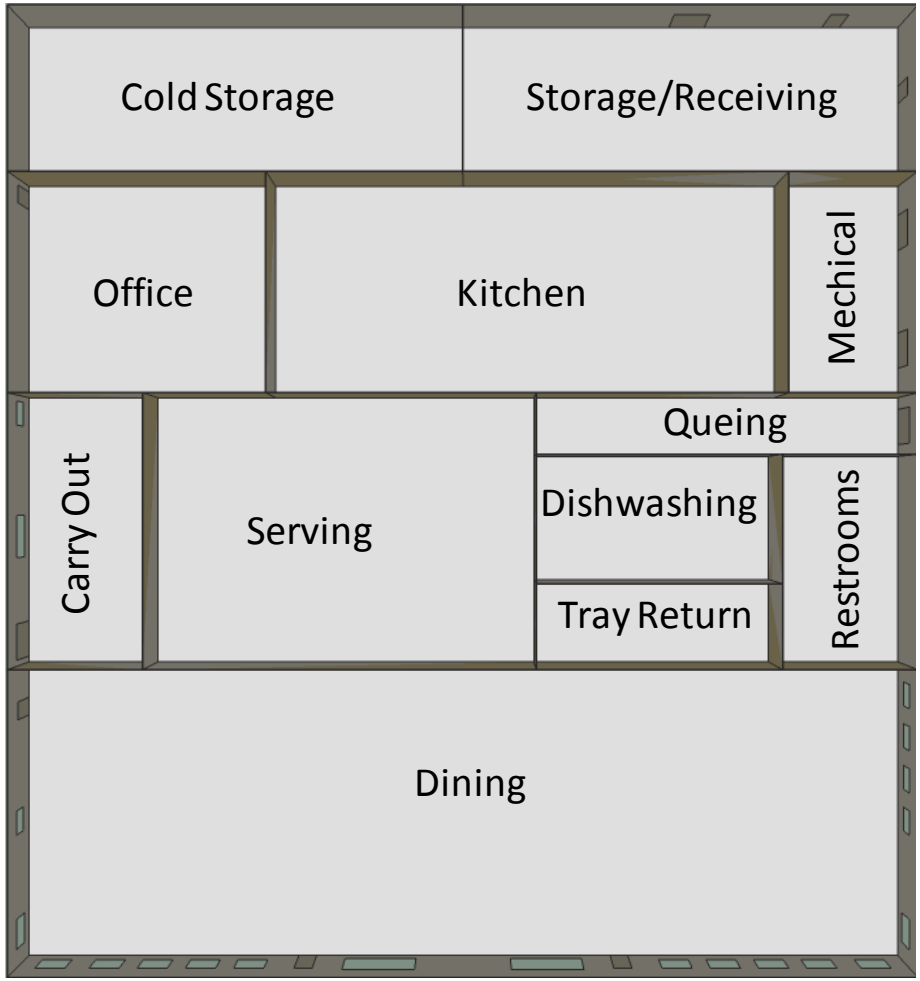
Tactical Equipment Maintenance Facility (TEMF)

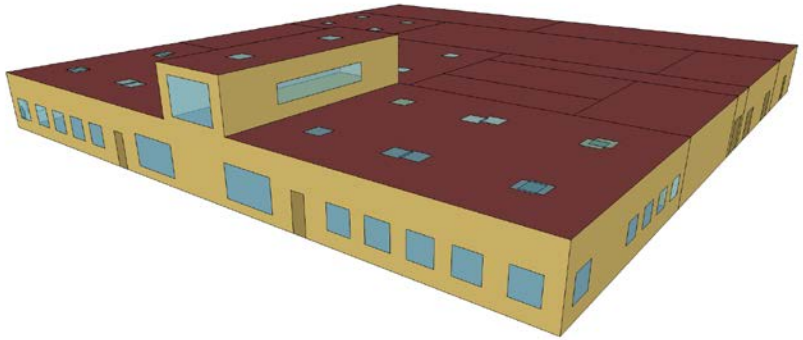


1A Miami
2A Houston
2B Phoenix
3A Memphis
3B El Paso
3C San Francisco
4A Baltimore
4B Albuquerque
4C Seattle
5A Chicago
5B Colorado Springs
6A Burlington
6B Helena
7A Duluth
8A Fairbanks

Image credit: Rois Langner, NREL

DFAC





Baseline Model:
108th ADA Complex – DFAC, Fort Bragg, NC
March, 2010

Image credit: Rois Langner, NREL

DFAC – EEMs

Envelope

- ASHRAE 90.1-2007 compliant insulation levels for climate zones 1A-3C

- Passive House insulation levels for climate zones 4A-8A
  - Reduced infiltration rates

R-Value per Climate Zone		1A	2A-B	3A-B	3C	4A-C	5A-B	6A-B	7A	8A
Wall	ASHRAE	13	13	13	13	13	13 + 3.8 ci	13 + 3.8 ci	13 + 7.5 ci	13 + 7.5 ci
	Passive House	13	13	24	13	31	38	47	63	71
Roof	ASHRAE	15	15	15	15	15	15	15	15	20
	Passive House	19	19	35	15	47	57	71	94	106

http://www.passiv.de

DFAC – EEMs

Lighting and Daylighting

- **Reduced lighting power densities in all zones**
  - **Occupancy sensors**
- **Daylighting and daylighting controls**

	ASHRAE Lighting Power Density [W/ft²]	Target Lighting Power Density [W/ft²]	Target Illuminance at Task [fc]
Dining Area	0.9	0.5	20
Kitchen	1.2	0.65	50
Serving	1.2	0.7	50
Office	1.1	0.9	40

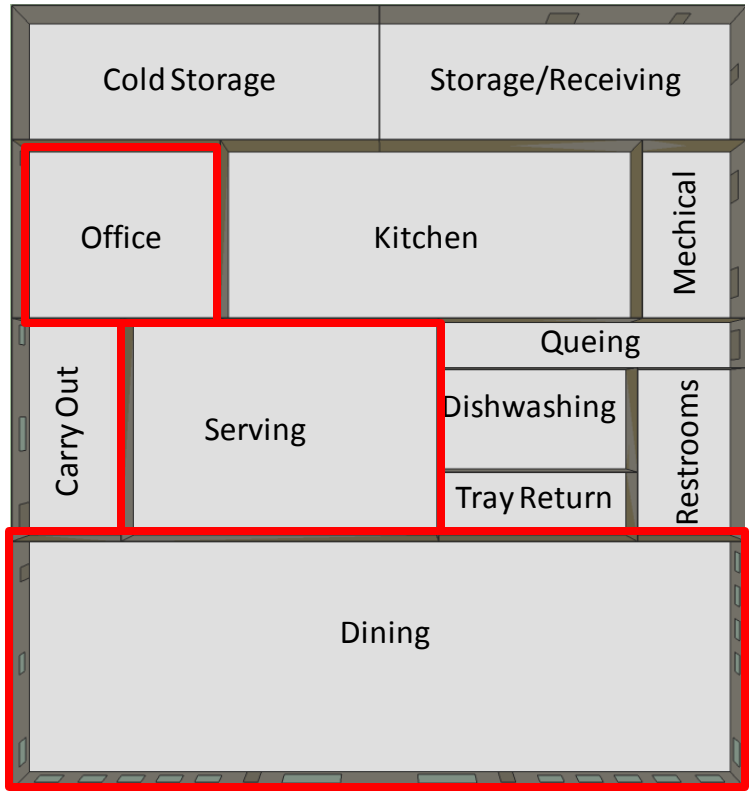


Image credit: Rois Langner, NREL

DFAC – EEMs

HVAC

- High efficiency HVAC – Increased efficiency:
  - Fans
  - Cooling coil
- Transfer air –
  Dining → Serving area

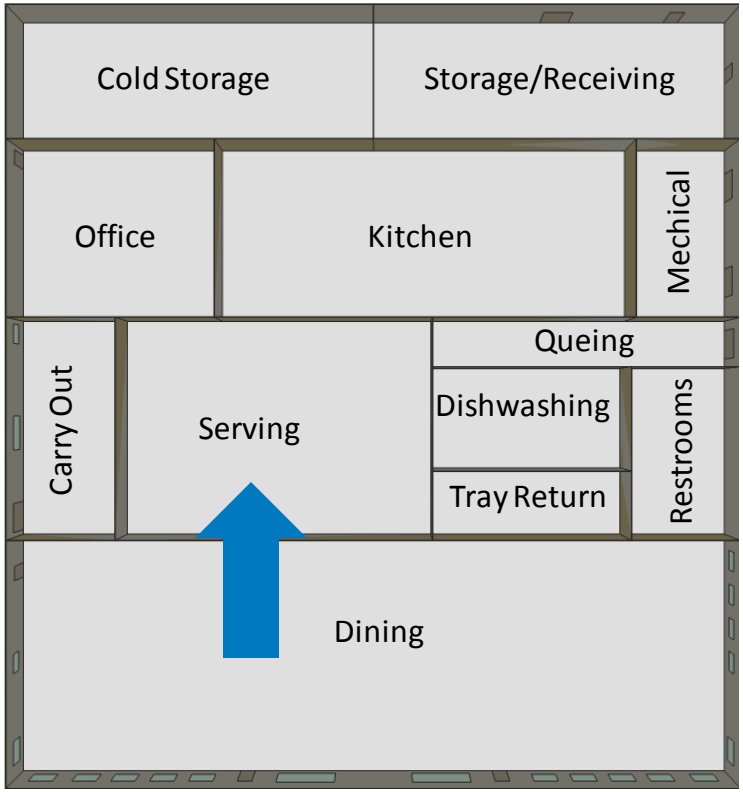


Image credit: Rois Langner, NREL

DFAC – EEMs

Kitchen Equipment

- High efficiency kitchen equipment
- All-electric kitchen equipment
- Back-shelf hoods with DCV (main kitchen hoods)
- Increased efficiency in refrigeration units
- Dishwasher exhaust heat recovery

Image credit: Don Fisher, Fisher Nickel, Inc.

DFAC – *Site* Energy Savings

Site Energy Savings Compared to Baseline	Baseline EUI [kBtu/ft^2]	Savings From EEMs with High Efficiency Kitchen Equipment	Savings From EEMs with *All-Electric* Kitchen Equipment
1A Miami	377	24%	38%
2A Houston	387	23%	35%
2B Phoenix	380	24%	35%
3A Memphis	396	22%	32%
3B El Paso	381	23%	34%
3C San Francisco	370	22%	33%
4A Baltimore	430	22%	31%
4B Albuquerque	400	22%	32%
4C Seattle	406	21%	31%
5A Chicago	463	22%	30%
5B Colorado Springs	426	23%	32%
6A Burlington	503	23%	29%
6B Helena	467	23%	30%
7A Duluth	540	23%	29%
8A Fairbanks	669	25%	28%

DFAC – *Site* Energy Savings

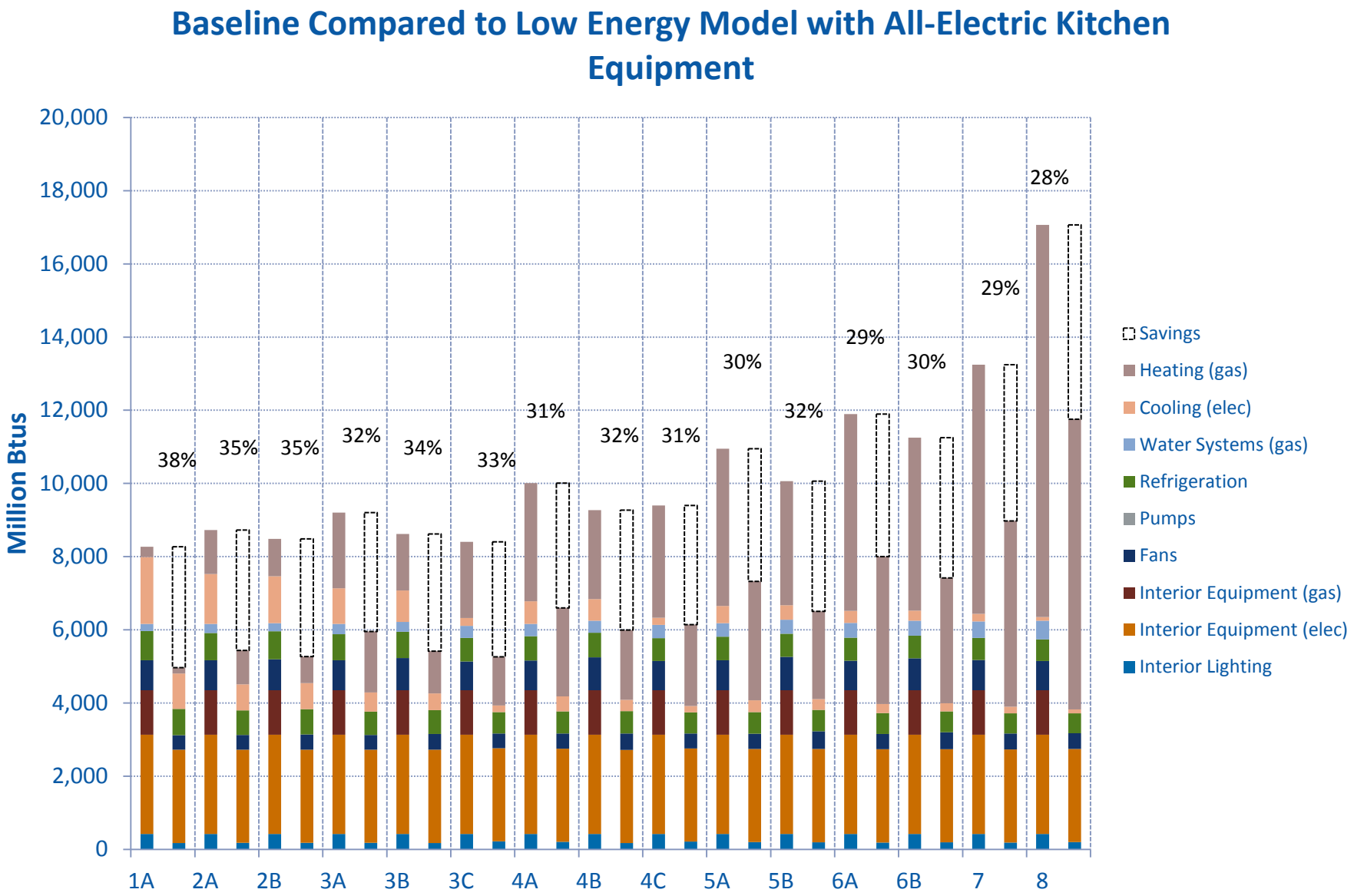
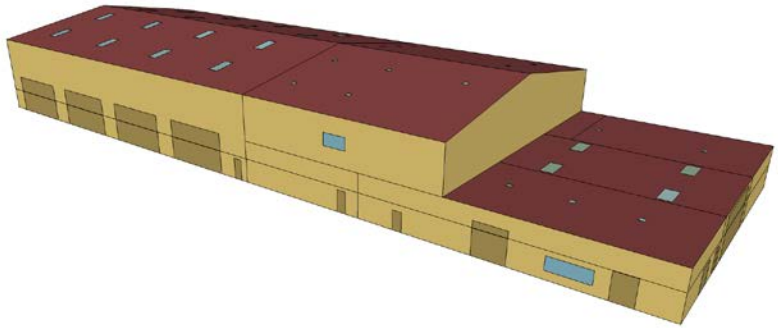


Figure credit: Rois Langner, NREL

DFAC – *Source* Energy Savings

Source Energy Savings Compared to Baseline	Baseline Source EUI [kBtu/ft^2]	CBECS 2003 Source EUI [kBtu/ft^2] (Fast Food)	Low Energy Model with All-Electric Kitchen Equipment Source EUI [kBtu/ft^2]	Savings of Low Energy Model to Baseline	Savings of Low Energy Model to CBECS 2003	Savings of Low Energy Model to CBECS 2003 with Added Cogen System
1A Miami	1016	902	722	29%	20%	63%
2A Houston	985	871	721	27%	17%	59%
2B Phoenix	972	741	713	27%	4%	53%
3A Memphis	965	741	728	25%	2%	49%
3B El Paso	934	745	699	25%	6%	53%
3C San Francisco	846	648	669	21%	-3%	47%
4A Baltimore	961	739	753	22%	-2%	44%
4B Albuquerque	935	587	716	23%	-22%	35%
4C Seattle	888	597	710	20%	-19%	35%
5A Chicago	987	719	780	21%	-9%	38%
5B Colorado Springs	949	678	748	21%	-10%	40%
6A Burlington	1013	797	805	21%	-1%	40%
6B Helena	985	751	782	21%	-4%	40%
7A Duluth	1061	851	848	20%	0%	38%
8A Fairbanks	1218	975	974	20%	0%	32%

TEMF



Baseline Model:
Vehicle Maintenance Shop 7th Transportation Battalion
PN-20807 Fort Bragg, NC
FY-2010

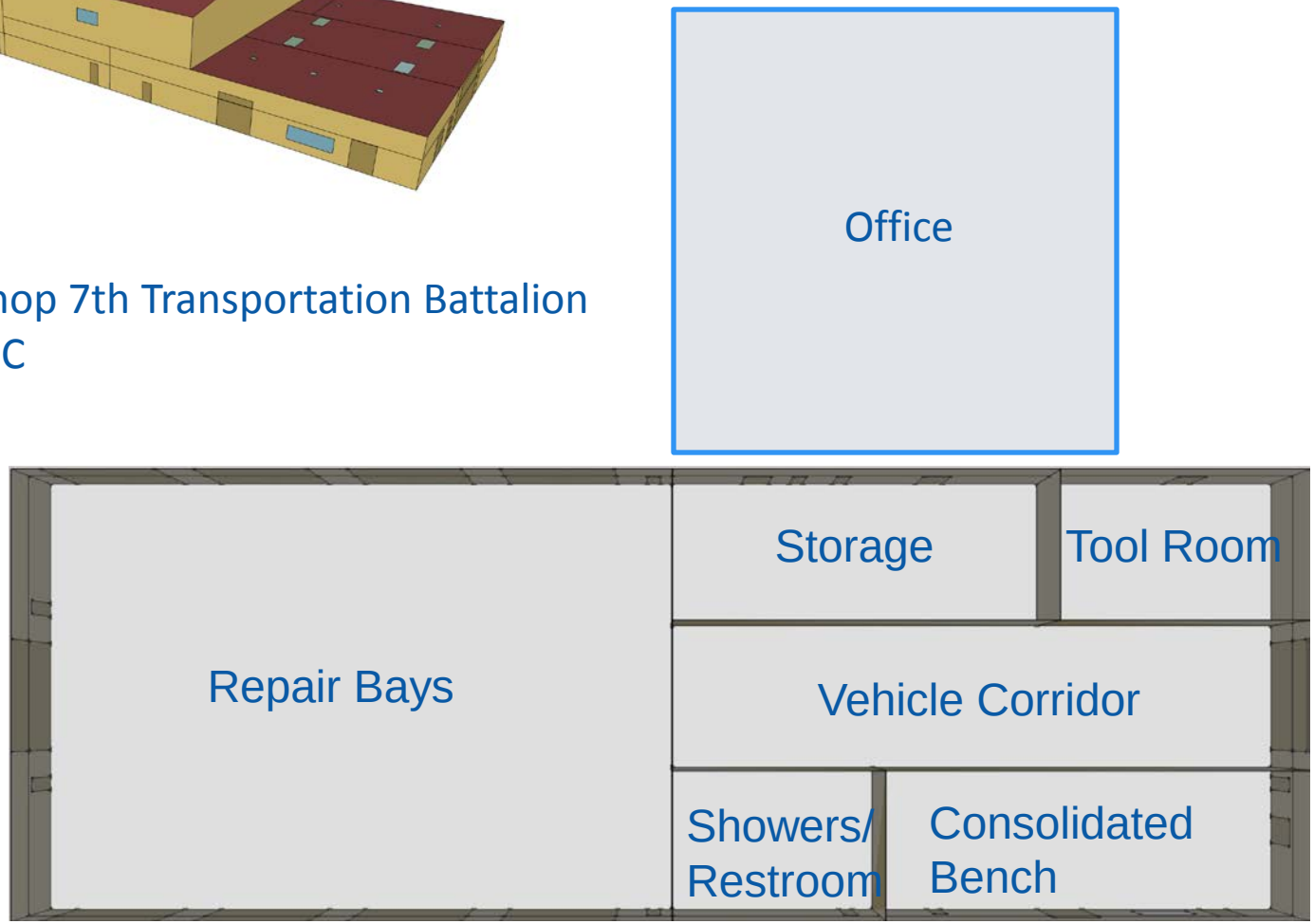


Image credit: Rois Langner, NREL

TEMF – EEMs

Envelope

- ASHRAE 90.1-2007 compliant insulation levels for climate zones 1A-2B, 3C

- Passive House insulation levels for climate zones 3A, 3B, 4A-8A
    - Reduced infiltration rates

TEMF – EEMs

Lighting and Daylighting

- **Reduced lighting power densities**
  - **Occupancy sensors**

	ASHRAE Lighting Power Density [W/ft²]	Target Lighting Power Density [W/ft²]	Target Illuminance at Task [fc]
Repair Bays	1.9	0.85	50
Consolidated Bench	1.9	0.55	50
Storage (Occupied)	1.9	0.65	40
Office	1.1	0.7	40

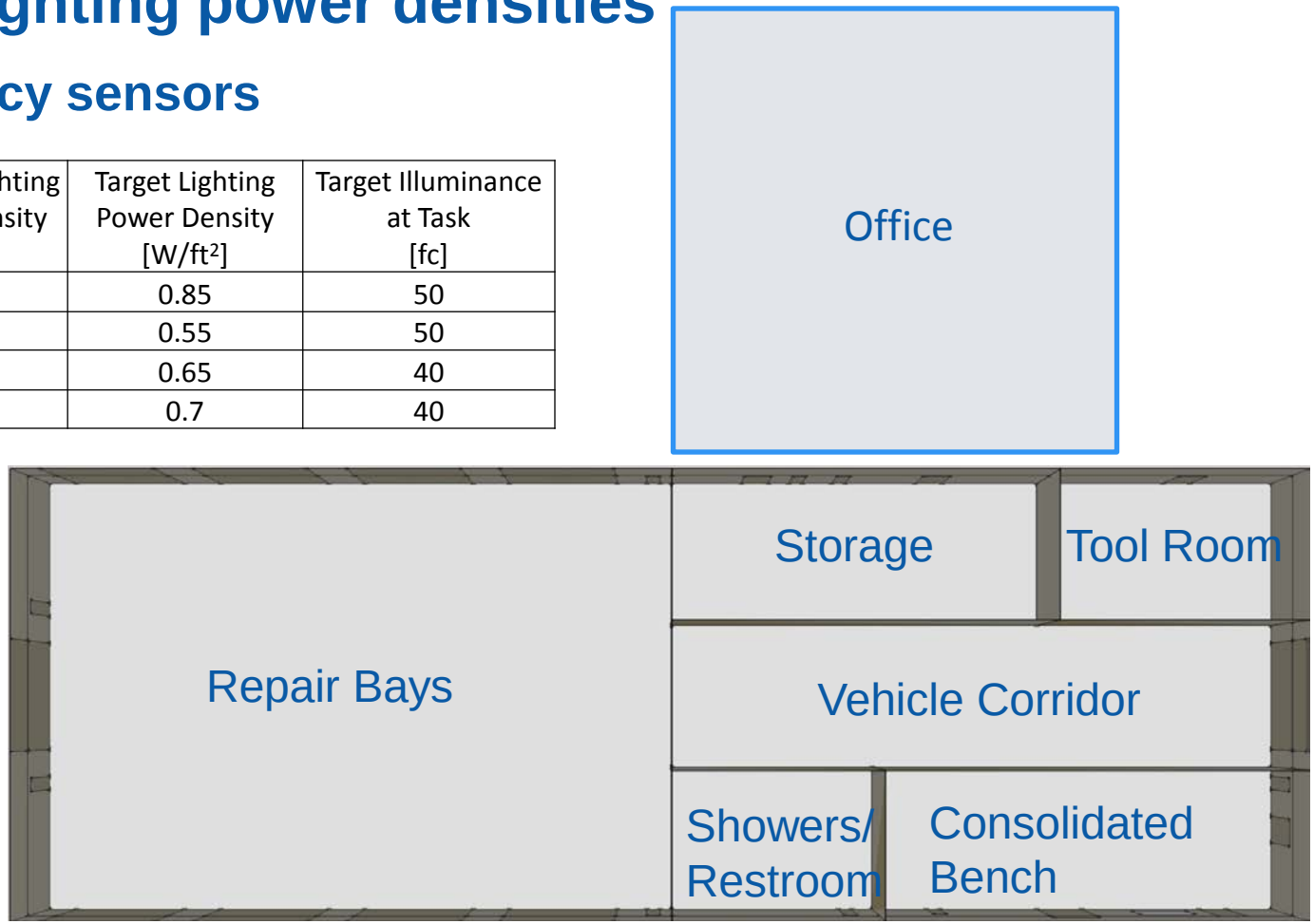


Image credit: Rois Langner, NREL

TEMF – EEMs

Lighting and Daylighting

- **Increased daylighting**
  - **Daylighting controls**
  - **Office, consolidated bench, repair bays**

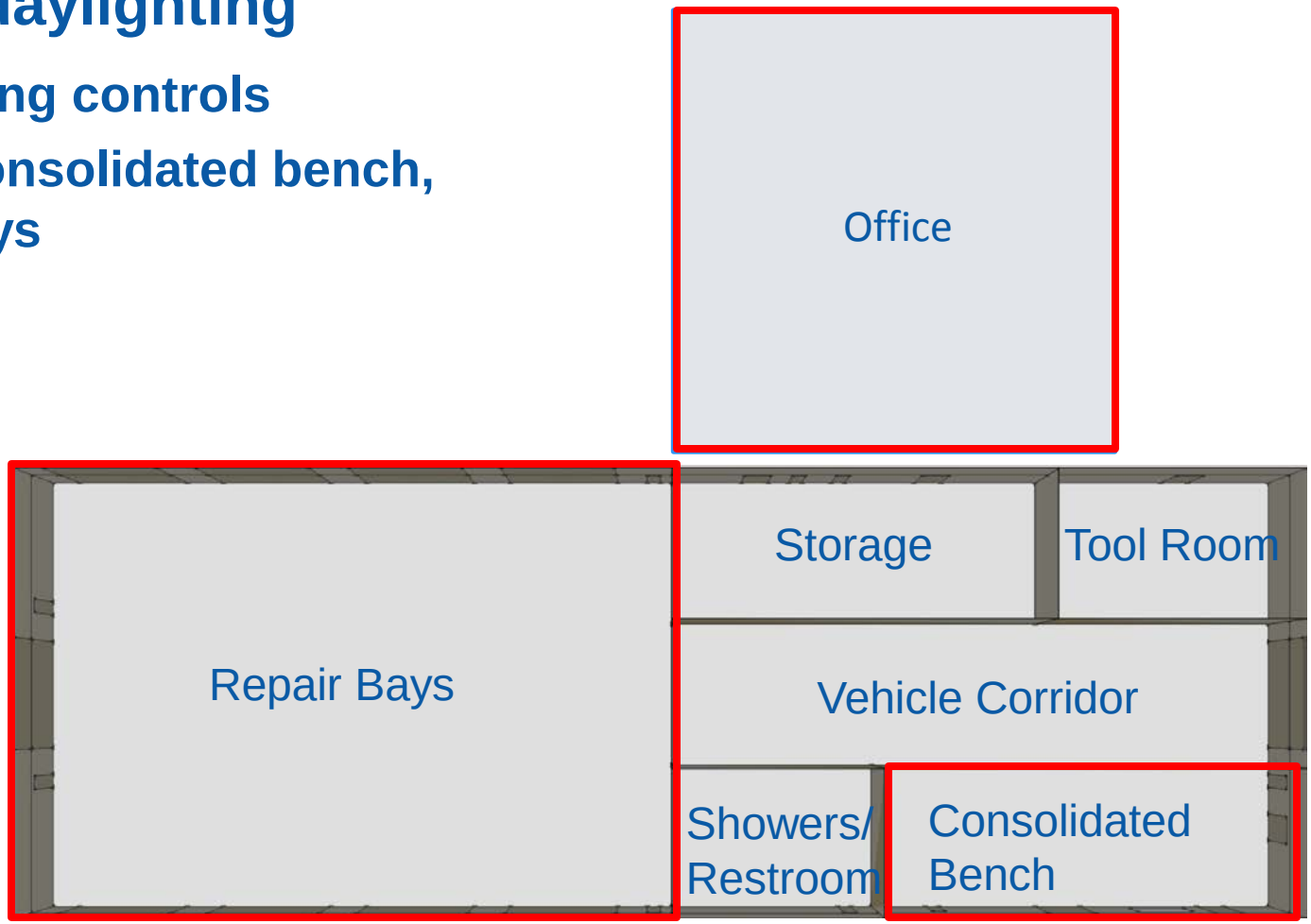


Image credit: Rois Langner, NREL

TEMF – EEMs

HVAC

- **High efficiency HVAC – Increased efficiency:**
  - **Fans, VAV**
  - **Cooling coil**

- **Reduced ventilation in repair bays**
  - **1.5 cfm/ft^2 → *0.12 cfm/ft^2*****
    18-36% savings!

*Values based off of:
ASHRAE Standard 62.1-2007Appendix B,
IAQ procedure for shipping/receiving areas

Image credit: Alexander Zhivov, USACE

TEMF – EEMs

HVAC

- Transpired solar collectors (TSC) (climate zones 2A-8A)

- Radiant floors (climate zones 2A-8A)

Image credit: NREL PIX

TEMF – *Site* Energy Savings

Site Energy Savings Compared to Baseline	Baseline EUI [kBtu/ft^2]	Savings From EEMs without TSC or Radiant Floors	Savings From EEMs with TSC	Savings From EEMs with Radiant Floors	Savings From EEMs with TSC and Radiant Floors
1A Miami	27	43%	43%	38%	39%
2A Houston	33	39%	41%	40%	42%
2B Phoenix	31	39%	40%	37%	39%
3A Memphis	41	48%	51%	48%	51%
3B El Paso	36	46%	48%	46%	48%
3C San Francisco	32	43%	45%	47%	49%
4A Baltimore	55	55%	59%	55%	58%
4B Albuquerque	46	54%	58%	54%	57%
4C Seattle	51	55%	58%	55%	57%
5A Chicago	68	57%	61%	57%	60%
5B Colorado Springs	58	56%	62%	56%	61%
6A Burlington	78	58%	62%	58%	62%
6B Helena	74	59%	63%	59%	62%
7A Duluth	94	58%	63%	59%	63%
8A Fairbanks	138	55%	57%	57%	59%

TEMF – *Site* Energy Savings

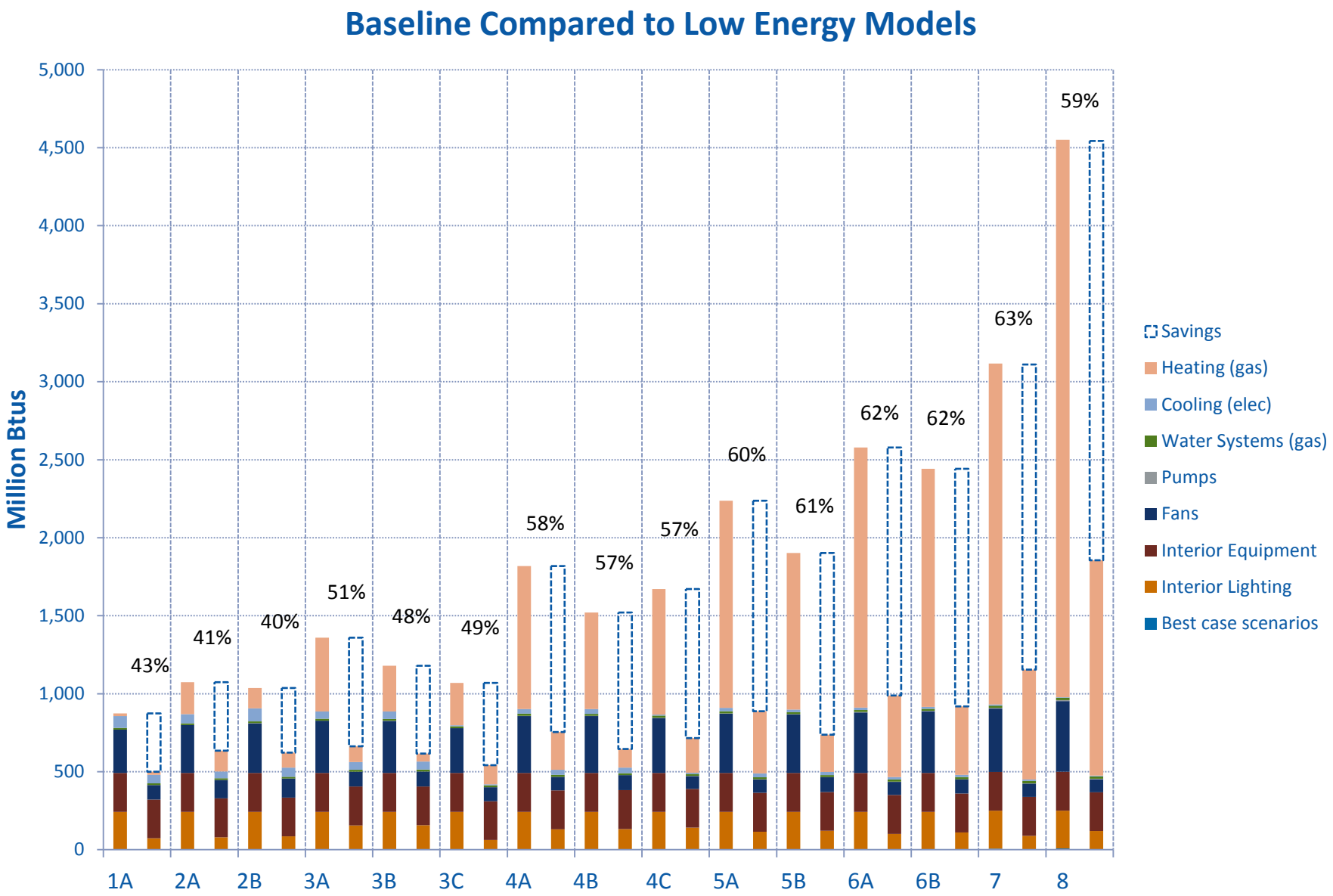
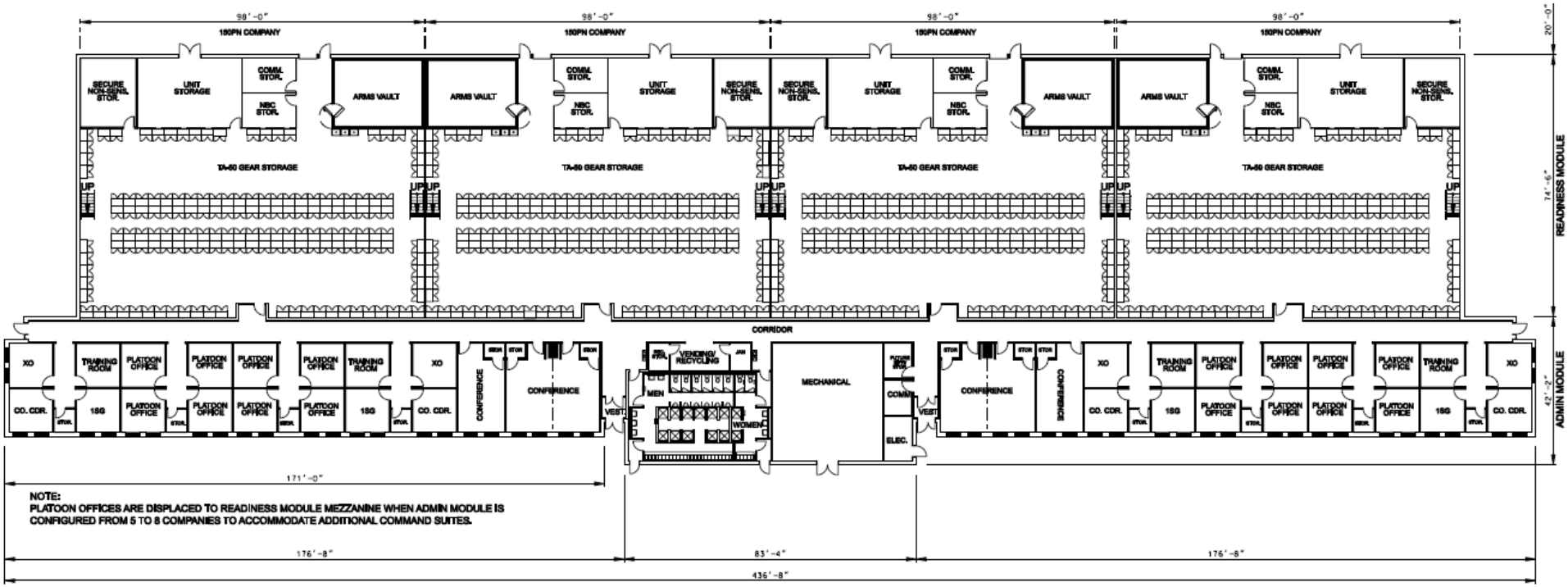


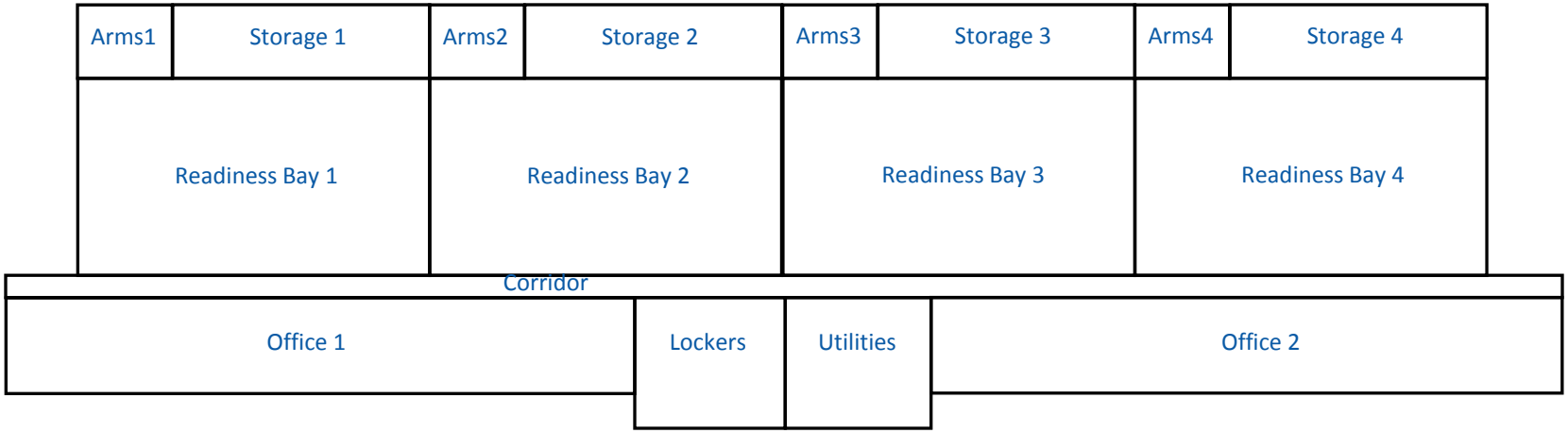
Figure credit: Rois Langner, NREL

TEMF – *Source* Energy Savings

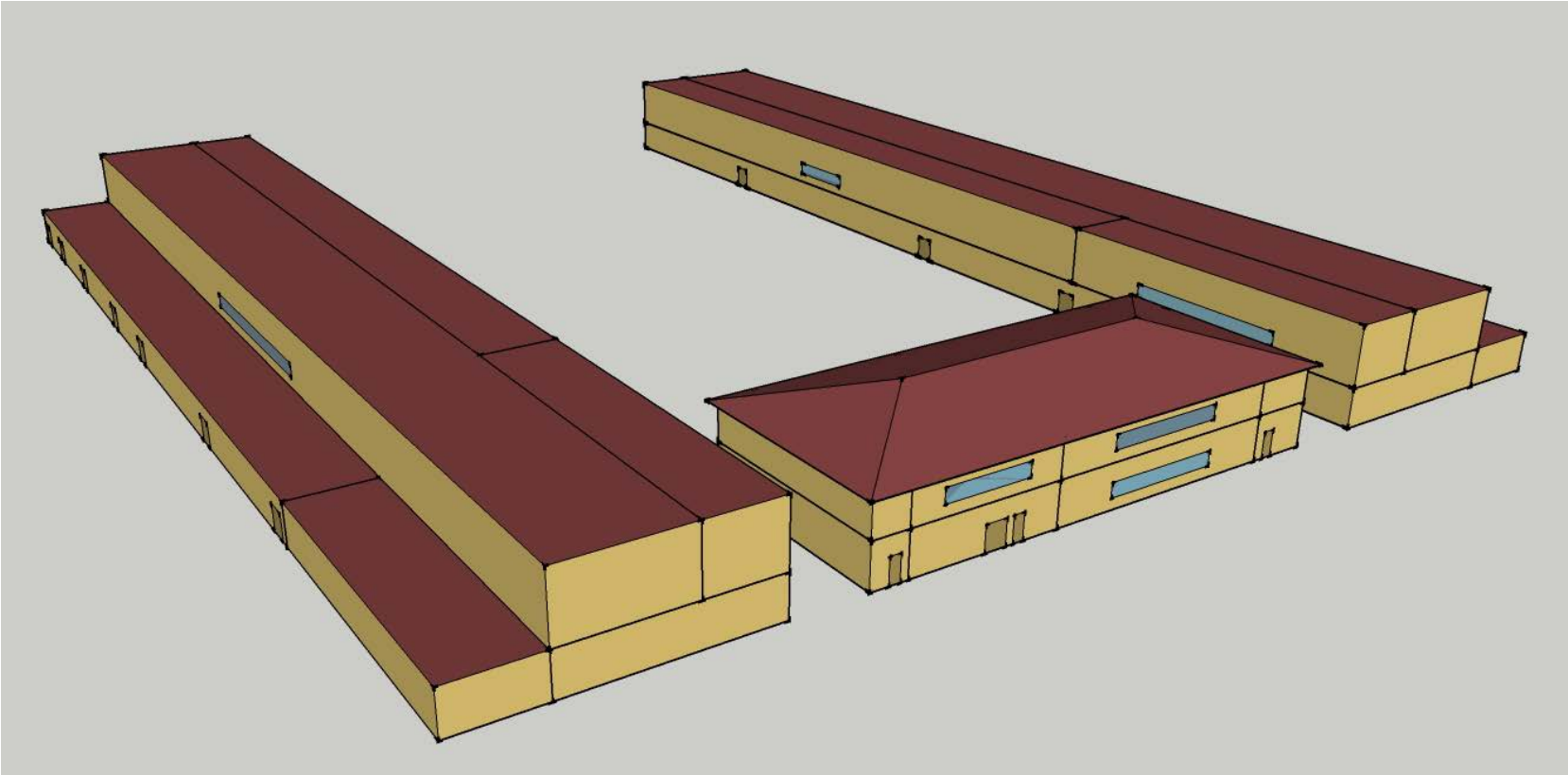
Source Energy Savings Compared to Baseline	Baseline Source EUI [kBtu/ft^2]	CBECS 2003 Source EUI [kBtu/ft^2] (Other Repair Service)	Low Energy Model Source EUI [kBtu/ft^2]	Savings of Low Energy Model to Baseline	Savings of Low Energy Model to CBECS 2003	Savings of Low Energy Model to CBECS 2003 with Added Cogen System
1A Miami	87	204	49	44%	76%	89%
2A Houston	94	187	54	42%	71%	85%
2B Phoenix	95	151	56	42%	63%	82%
3A Memphis	104	159	59	43%	63%	82%
3B El Paso	98	146	58	41%	60%	81%
3C San Francisco	89	136	46	49%	66%	83%
4A Baltimore	120	164	59	51%	64%	81%
4B Albuquerque	110	114	56	49%	51%	75%
4C Seattle	113	117	56	50%	52%	74%
5A Chicago	133	166	61	54%	63%	78%
5B Colorado Springs	122	159	57	53%	64%	80%
6A Burlington	144	189	63	56%	67%	79%
6B Helena	140	149	62	56%	59%	75%
7A Duluth	162	180	67	59%	63%	75%
8A Fairbanks	211	225	91	57%	60%	69%

COF – Company Operations Facility



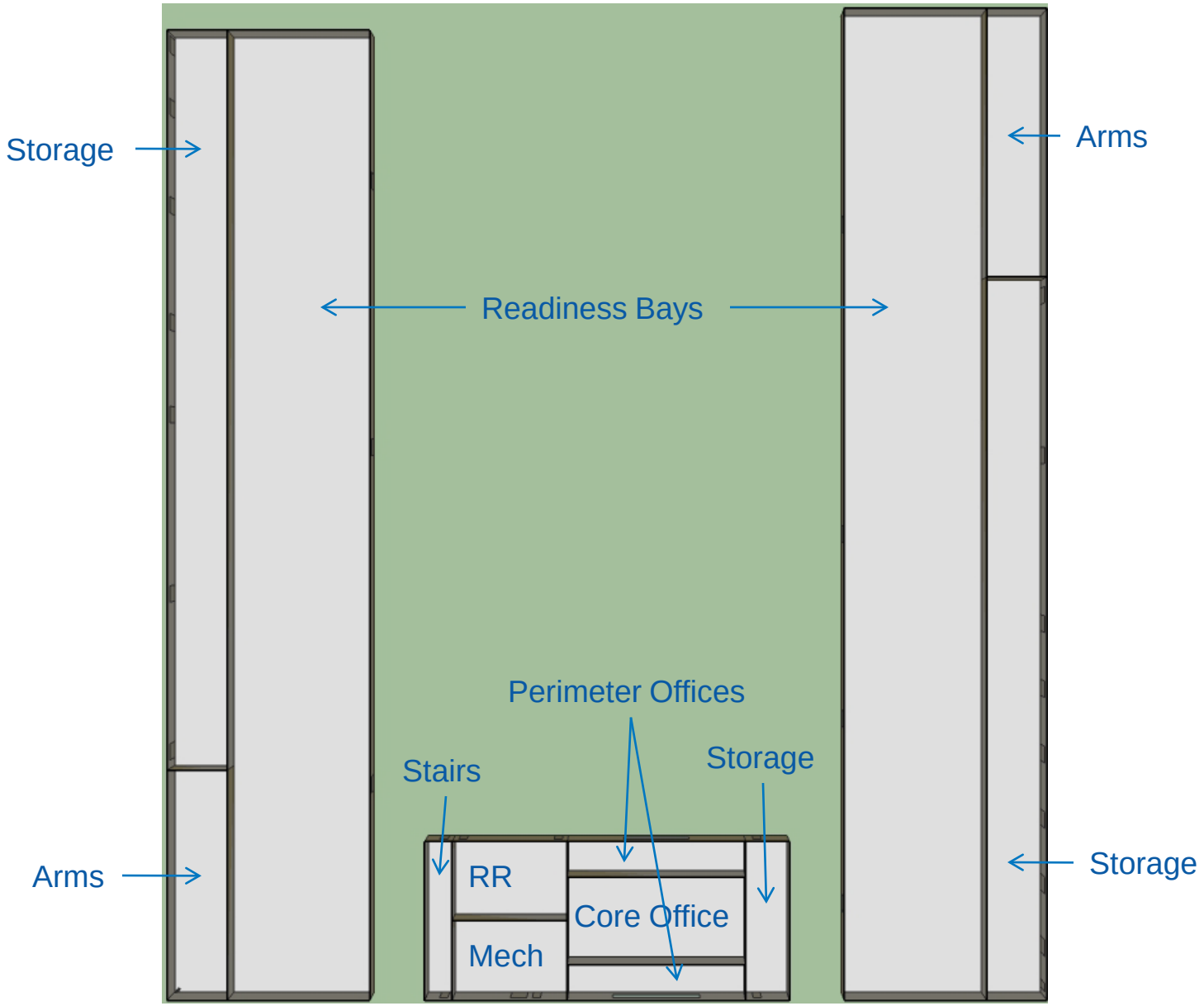


COF Energy Model

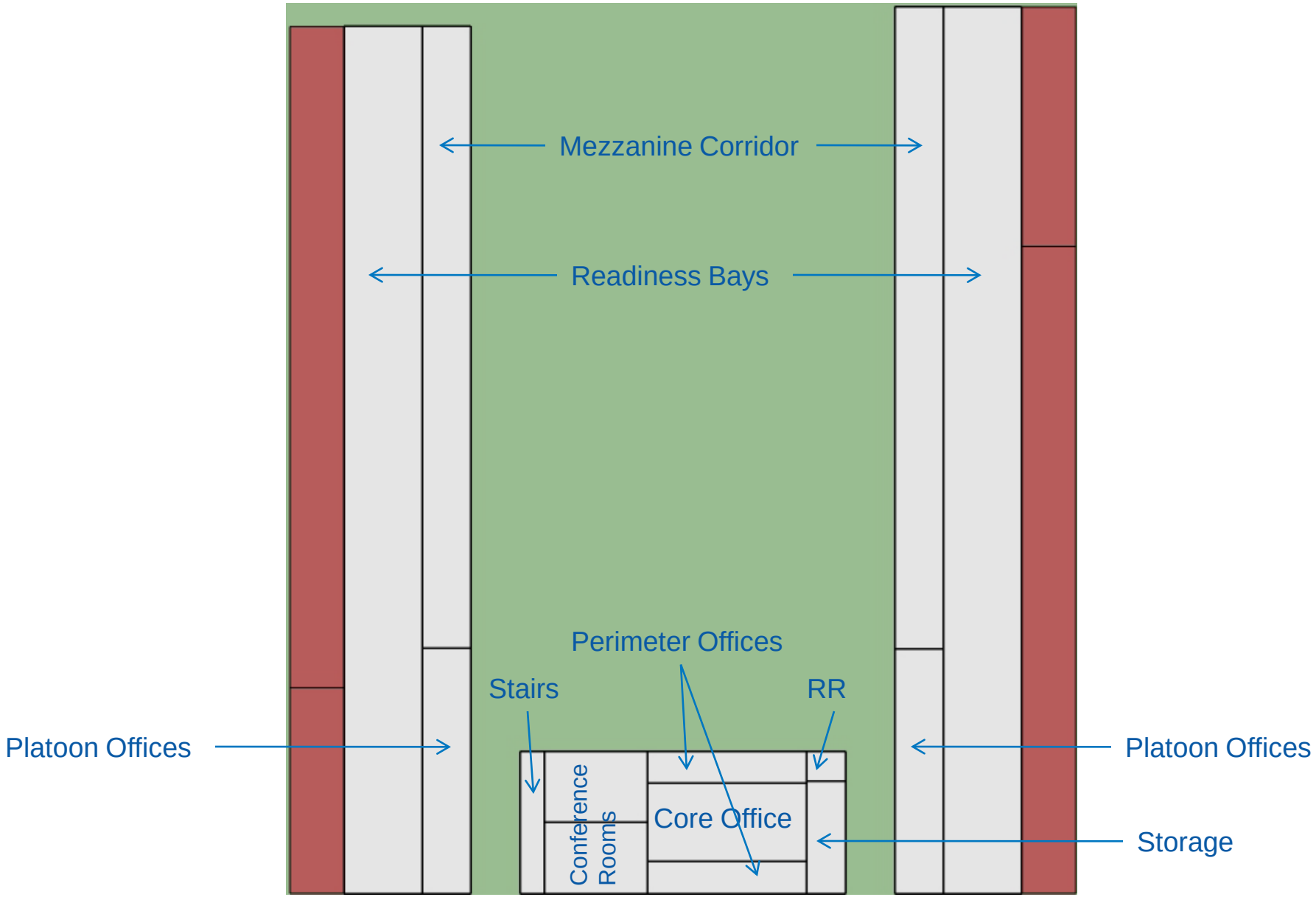


Baseline*: 4th Brigade Combat Team Complex (Heavy); Fort Stewart, Georgia

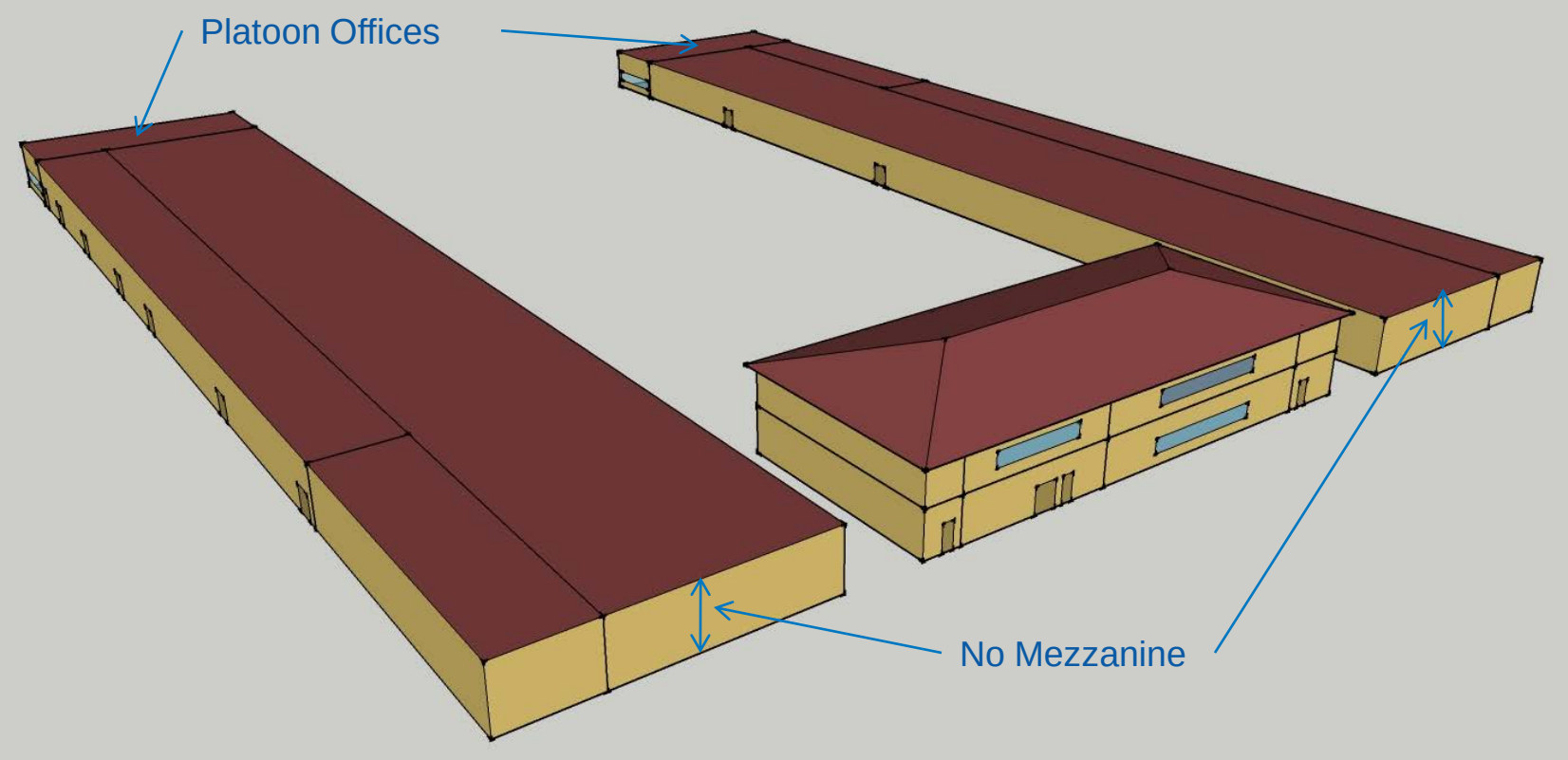
COF Thermal Zones – First Floor



COF Thermal Zones – Second Floor



COF Energy Model – Alternate Construction



- Considered the energy impacts of re-designing the readiness bays without mezzanines – reducing the volume of air that needs to be heated and cooled

Energy Efficiency Measures

- Baseline*: 4th Brigade Combat Team Complex (Heavy); Fort Stewart, Georgia

Parameter	Baseline*	Low Energy Option
Envelope	ASHRAE 90.1-2007 compliant envelope constructions	Passiv Haus insulation, Passiv Haus rated windows– applied to whole building. Reduced infiltration rates from 0.4 cfm/ft2 to 0.15 cfm/ft2
Lighting	Lighting Power Densities calculated from drawings	Lighting Power Densities recommended by Atellier Ten
Daylighting	No daylighting controls	-Increased Skylight to Floor Area (SFA) fraction to 3% over readiness bays, platoon offices, mezzanine corridor, and storage spaces - Added daylighting controls with 500 lux setpoint
HVAC Efficiency	-Standard efficiency CV fans - Chiller Efficiency: 2.9 COP - Condensing Boiler	-Increased fan efficiency (recommendations from Al Woody): efficiencies increased to 70% - Added VAV fans - Chiller COP increased to 4.45 - Condensing Boiler
Energy Recovery	None	Climate zones 1A-4B (Readiness Bays and Admin)
Indirect Evaporative Cooling	None	Climate zones 4C-8A – IDEC and DCV (Admin Building)
DOAS with Fan Coils in Readiness Bays	None	Climate zones 2B and 3B (Readiness Bays)
Transpired Solar Collectors	None	Climate zones 2A-8

Site EUI For Each EEM

1. Whole building baseline
2. Baseline model of just the readiness bays
3. Readiness Bays baseline with alternate construction
4. Readiness Bays - Reduced lighting power density per Atelier Ten recommendations
5. Readiness Bays - Reduced LPD and increased daylighting in readiness bays (added skylights to 3% of roof area)
6. Readiness Bays – Reduced LPD, passiv haus envelope construction, and reduced infiltration rates
7. Readiness Bays – Reduced LPD, increased daylighting, passiv haus envelope construction, and reduced infiltration rates
8. Readiness Bays – Cool roof added to climate zones 1-5
9. Readiness Bays – High efficiency HVAC – including ERV and DCV for climate zones 1A-4B, and IDEC and DCV for climate zones 4C-8A
10. Readiness Bays – High efficiency HVAC with DOAS and fan coil unit
11. Readiness Bays – Best options out of EEMs 4-10 (highlighted options)
12. Whole Building with best options out of EEMs 4-10 for Readiness Bays and EEM 8 applied to Admin
13. Whole Building – EEM 12 with alternate construction applied to Readiness Bays

			EEMs Applied Individually to Readiness Bays Baseline										
EEMs:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Site Energy [kBtu/ft2]	**Whole Building Baseline**	**Readi-Bays Baseline**	**Readi-Bays - Baseline with Alternate Construction**	**Readi-Bays - Baseline with Lighting Power Density Reduction**	**Readi-Bays - Baseline with LPD Reduction and Increased Daylighting**	**Readi-Bays - Baseline with LPD Reduction and Passiv Haus Envelope**	**Readi-Bays - Baseline w/ LPD Reduction with Increased Daylighting and Passiv Haus Envelope**	**Readi-Bays - Baseline with Cool Roof in Climate Zones 1-5**	**Readi-Bays - Baseline w/ High Efficiency HVAC - ERV and VAV (CZ 1A-4B), IDEC and VAV (CZ 4C-8A)**	**Readi-Bays - w/ High Efficiency HVAC - DOAS, ERV and Fan Coils**	**Readi-Bays - Best of EEMs 4-10 (EEMs highlighted in gray)**	**Whole Building - Best of EEMs 4-10 for Readi-Bays, EEM 8 applied to Admin**	**Whole Building - EEM 13 with Alternate Construction for Readi-Bays (EEM 3)**
1A Miami	58	47	40	44	42	38	37	45	38	40	27	29	23
2A Houston	62	53	39	51	50	39	38	53	40	43	26	30	24
2B Phoenix	60	48	32	46	44	35	35	47	42	38	32	35	29
3A Memphis	72	60	42	59	57	43	42	60	42	48	26	30	25
3B El Paso	59	48	31	46	44	34	33	48	39	37	31	34	29
3C San Francisco	54	43	29	41	39	30	29	43	34	37	20	25	21
4A Baltimore	78	70	48	68	67	50	48	70	43	57	25	29	25
4B Albuquerque	67	57	38	56	54	39	38	57	39	44	21	26	21
4C Seattle	68	57	39	56	55	40	38	58	41	46	21	26	23
5A Chicago	94	83	59	82	81	58	57	84	50	70	24	29	25
5B Colorado Springs	79	69	47	67	66	47	45	69	44	56	20	25	21
6A Burlington	103	92	66	91	90	65	63	92	52	81	24	29	25
6B Helena	94	83	58	82	81	56	55	83	51	70	22	27	23
7A Duluth	117	108	78	107	106	76	74	108	58	98	24	30	26
8A Fairbanks	163	152	112	151	152	107	105	152	76	155	32	37	33

Site Energy Savings For Each EEM

1. Whole building baseline
2. Baseline model of just the readiness bays
3. Readiness Bays baseline with alternate construction
4. Readiness Bays - Reduced lighting power density per Atelier Ten recommendations
5. Readiness Bays - Reduced LPD and increased daylighting in readiness bays (added skylights to 3% of roof area)
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12. Whole Building with best options out of EEMs 4-10 for Readiness Bays and EEM 8 applied to Admin
13. Whole Building – EEM 12 with alternate construction applied to Readiness Bays

			EEMs Applied Individually to Readiness Bays Baseline										
EEMs:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Site Energy Savings Compared to Baseline	**Whole Building Baseline**	**Readi-Bays Baseline**	**Readi-Bays - Baseline with Alternate Construction**	**Readi-Bays - Baseline with Lighting Power Density Reduction**	**Readi-Bays - Baseline with LPD Reduction and Increased Daylighting**	**Readi-Bays - Baseline with LPD Reduction and Passiv Haus Envelope**	**Readi-Bays - Baseline w/ LPD Reduction with Increased Daylighting and Passiv Haus Envelope**	**Readi-Bays - Baseline with Cool Roof in Climate Zones 1-5**	**Readi-Bays - Baseline w/ High Efficiency HVAC - ERV and VAV (CZ 1A-4B), IDEC and VAV (CZ 4C-8A)**	**Readi-Bays - w/ High Efficiency HVAC - DOAS, ERV and Fan Coils**	**Readi-Bays - Best of EEMs 4-10 (EEMs highlighted in gray)**	**Whole Building - Best of EEMs 4-10 for Readi-Bays, EEM 8 applied to Admin**	**Whole Building - EEM 13 with Alternate Construction for Readi-Bays (EEM 3)**
1A Miami	-	-	16%	6%	11%	20%	22%	5%	20%	15%	43%	50%	60%
2A Houston	-	-	26%	4%	7%	28%	29%	1%	25%	20%	51%	52%	61%
2B Phoenix	-	-	33%	5%	8%	26%	27%	2%	13%	21%	34%	42%	52%
3A Memphis	-	-	31%	3%	6%	29%	31%	0%	30%	19%	57%	58%	65%
3B El Paso	-	-	34%	4%	8%	29%	31%	1%	19%	24%	36%	42%	50%
3C San Francisco	-	-	33%	3%	8%	29%	33%	-2%	20%	14%	53%	54%	61%
4A Baltimore	-	-	31%	2%	5%	29%	31%	0%	38%	18%	65%	62%	68%
4B Albuquerque	-	-	34%	3%	6%	31%	33%	0%	32%	24%	63%	62%	69%
4C Seattle	-	-	32%	2%	4%	30%	33%	-1%	29%	20%	63%	62%	67%
5A Chicago	-	-	29%	1%	3%	30%	32%	-1%	40%	16%	71%	69%	73%
5B Colorado Springs	-	-	31%	2%	4%	31%	34%	-1%	36%	19%	70%	68%	73%
6A Burlington	-	-	29%	1%	2%	30%	31%	0%	44%	12%	74%	72%	76%
6B Helena	-	-	31%	1%	2%	32%	34%	0%	38%	16%	73%	71%	75%
7A Duluth	-	-	28%	1%	2%	30%	31%	0%	46%	9%	77%	75%	78%
8A Fairbanks	-	-	26%	1%	0%	30%	31%	0%	50%	-2%	79%	77%	80%

COF *Site* Energy Budgets [kBtu/ft2]

Climate Zone	City	CBECS 2003 Site Energy (Whole Building - Governement Office + Other Public Assembly)	Baseline Model	CBECS Target	Low-Energy Model (w/Alt Construction)	% Difference from CBECS 2003
1A	Miami, FL	47	58	17	23	51%
2A	Houston, TX	47	62	17	24	49%
2B	Phoenix, AZ	46	60	16	29	37%
3A	Memphis, TN	46	72	16	25	45%
3B	El Paso, TX	43	59	15	29	33%
3C	San Francisco, CA	42	54	15	21	49%
4A	Baltimore, MD	51	78	18	25	52%
4B	Albuquerque, NM	45	67	16	21	54%
4C	Seattle, WA	47	68	16	23	52%
5A	Chicago, IL	55	94	19	25	54%
5B	Colorado Springs, CO	49	79	17	21	57%
6A	Burlington, VT	61	103	21	25	59%
6B	Helena, MT	55	94	19	23	58%
7	Duluth, MN	65	117	23	26	60%
8	Fairbanks, AK	87	163	30	33	62%

COF *Source* Energy Budgets [kBtu/ft2]

Climate Zone	City	CBECS 2003 Source Energy (Whole Building - Governement Office + Other Public Assembly)	Baseline Model	CBECS Target	Low-Energy Model (w/Alt Construction)	% Difference from CBECS 2003	% Difference from CBECS with Cogen system	Low-Energy % Gas	Low-Energy % Electricity
1A	Miami, FL	111	166	39	74	34%	69%	2%	98%
2A	Houston, TX	103	154	36	69	32%	66%	7%	93%
2B	Phoenix, AZ	83	161	29	80	3%	51%	9%	91%
3A	Memphis, TN	86	159	30	69	19%	58%	11%	89%
3B	El Paso, TX	79	139	28	72	9%	49%	17%	83%
3C	San Francisco, CA	76	113	27	54	29%	61%	15%	85%
4A	Baltimore, MD	88	150	31	64	28%	61%	14%	86%
4B	Albuquerque, NM	62	140	22	56	9%	52%	11%	89%
4C	Seattle, WA	64	128	23	51	21%	53%	22%	78%
5A	Chicago, IL	89	171	31	62	31%	61%	17%	83%
5B	Colorado Springs, CO	80	149	28	52	36%	64%	17%	83%
6A	Burlington, VT	103	177	36	58	44%	68%	20%	80%
6B	Helena, MT	82	167	29	54	34%	62%	20%	80%
7	Duluth, MN	96	186	34	57	41%	64%	24%	76%
8	Fairbanks, AK	126	247	44	64	49%	66%	34%	66%

- *Cogen system assumes 37% electric efficiency and 80% overall efficiency, and that all of the energy is used.
  - Electric multiplier: 5.190 [kBtu/kBtu]
  - Hot Water Multiplier: 1.126 [kBtu/kBtu]

Thank You

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