EBC Energy in Buildings and Communities Programme

Annex 61 Business and Technical Concepts for Deep Energy Retrofits of Public Buildings

Deep Energy Retrofit of Buildings

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Typical Energy Efficiency Improvement Projects

- A part of major building renovation
- A part of minor building renovation
- Utilities modernization projects
- System retro/ongoing commissioning
- Dedicated energy projects using ESPC or UESC contracts
- Mechanical and electrical equipment/systems replacement

Reasons for major renovation

- ***Extension of the useful building life*** requiring overhaul of its structure, internal partitions and systems;
- ***Repurposing of the building***, e.g., renovation of old warehouses into luxury apartments (Soho area in New York, NY, or into boutique shops in Montreal, QC), or renovation of old Army barracks into offices);
- Bringing the building ***to compliance with new or updated codes***;
- ***Remediation of environmental problems*** (mold and mildew) and improvement of the visual and thermal comfort and indoor air quality,
- ***Adding the value*** to increase investment (increasing useful space and/or space attractiveness/quality) ***resulting in a higher sell or lease price***.

Major Renovation: Business as Usual

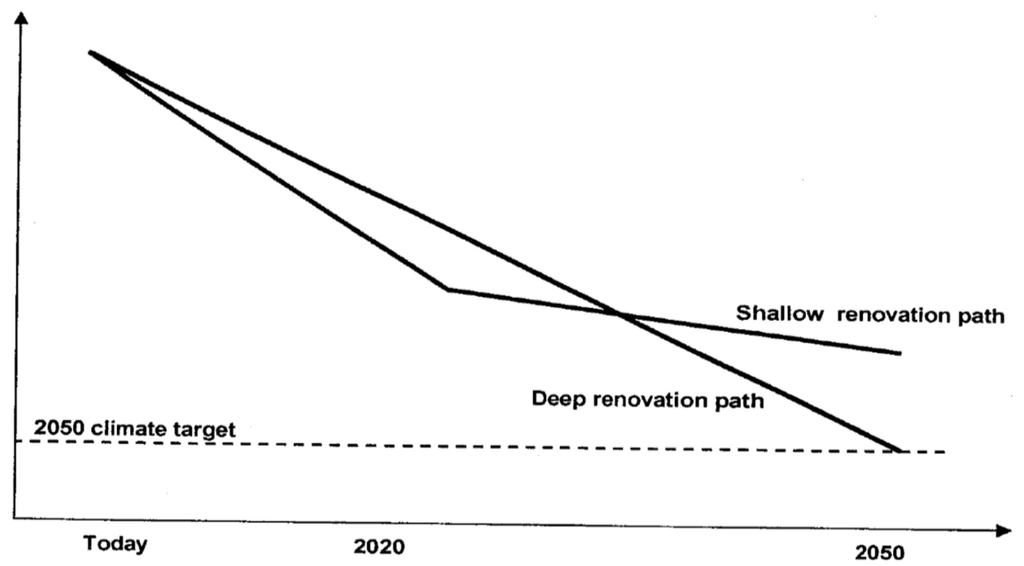
Examples of calculated % of energy use reduction (including plug-loads) with major renovation projects from pre-1980 baseline to current minimum energy standards

- USA :
  - Barracks (c.z. 1A – 8) EUI_{site}: **8-16%**
  - Administrative building: EUI_{site}: **8-22%**
- German Administrative Buildings (c.z. 5A) EUI_{site}: **40%**
- Danish School (c.z.6A): EUI_{site}: **19%**;
- Austrian residential building (c.z. 5A): EUI_{site}: **29%**

Timing a DER to Coincide with a Major Renovation

- Building is typically evacuated and gutted;
- Scaffolding is installed;
- Single pane and damaged windows are scheduled for replacement;
- Building envelope insulation is replaced and/or upgraded;
- Most of mechanical, electrical lighting, and energy conversion systems will be replaced
- ***A significant sum of money covering the cost of energy-related scope of the renovation designed to meet minimum energy code is already budgeted anyway.***

How to Meet Energy Goals?

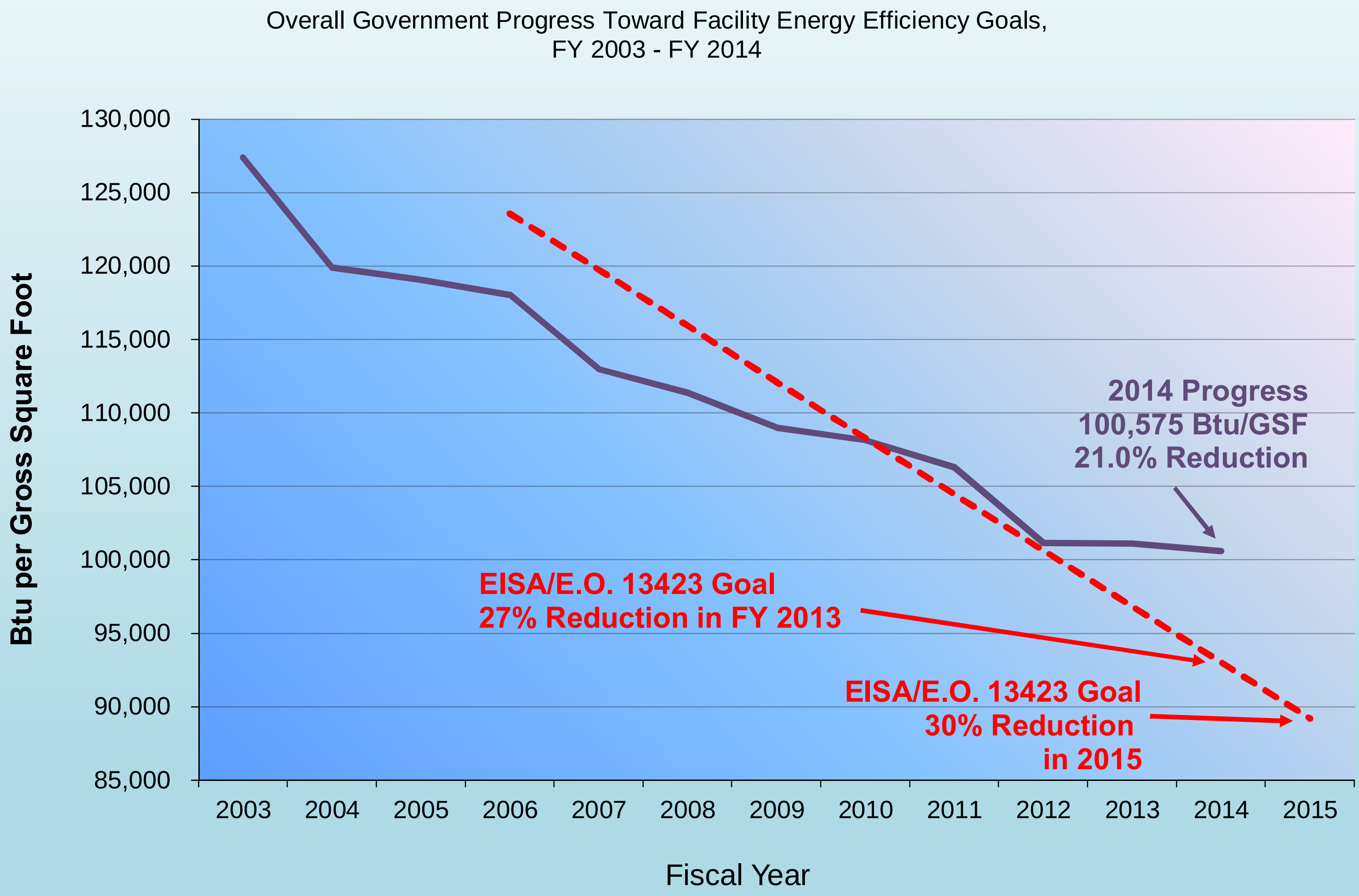


The speed trap of shallow renovation (from "Economics of Deep Renovation," *Ecofys* 2011

Spending available annual budgets for many cheaper shallow renovations Vs fewer, more expansive deep energy renovations may lead to unwanted, irreversible long-term consequences.

Looks better for short-term decisions, but may well fail to achieve long-term energy goals.

U.S. Federal Facilities: Energy Intensity (Btu/GSF) Reduction Vs. Goal



PRELIMINARY DATA

Annex 61 Business and Technical Concepts for Deep Energy Retrofits of Public Buildings

www.iea-annex61.org

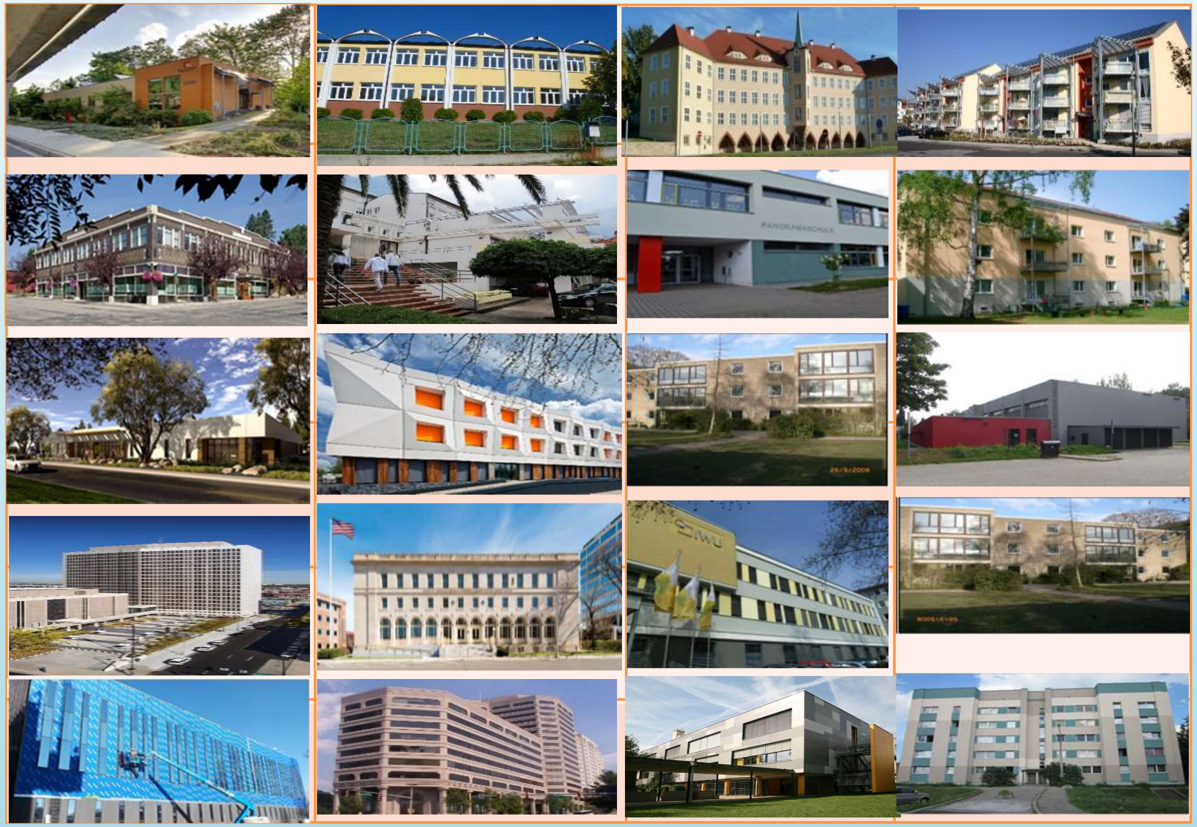
Annex 61 Objectives

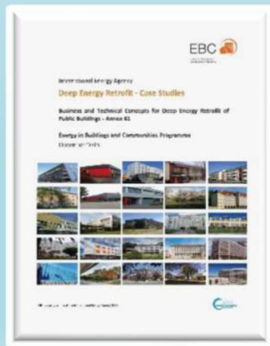
- To provide a framework and selected tools and guidelines to significantly reduce energy use (by more than 50%) in *public buildings undergoing major renovation*
- To gather and, in some cases, research, develop, and demonstrate *innovative and highly effective bundled packages of ECMs* for selected building types and climatic conditions
- To develop and demonstrate *innovative, highly resource-efficient business models for retrofitting buildings* using appropriate combinations of public and private funding

Annex 61 Scope

- Buildings with low internal loads (e.g., offices, barracks, dormitories, public housing, educational buildings, **undergoing MAJOR RENOVATIONS**
- Historic/listed buildings **are excluded**
- Buildings with high internal loads (e.g., dining facilities, hospitals, data centers) **are excluded**

Deep Energy Retrofit - Case Studies





26 well documented case studies from Austria, Denmark, Estonia, Germany, Ireland, Montenegro, The Netherlands and the USA.

Definition of DER

Annex 61 team has collected and documented 26 case studies from Austria, Denmark, Estonia, Germany, Ireland, Montenegro, The Netherlands and the USA in which site energy has been reduced by 50% or better.

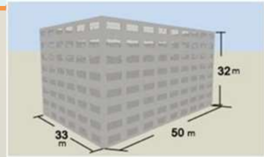
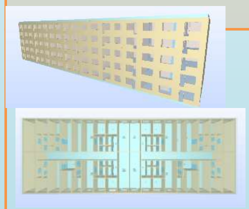
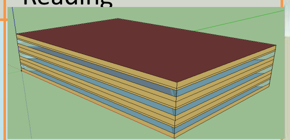
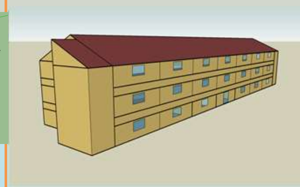
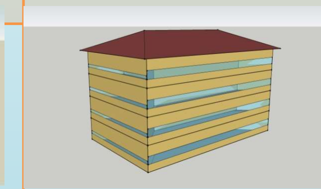
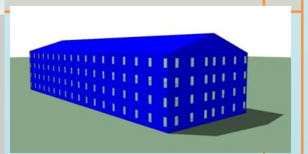
Based on anaysis of trends in policies from around the world and best practices including those, documented in case-studies, IEA EBC Annex 61 team has proposed the following definition of the Deep Energy Retrofit:

Deep Energy Retrofit (DER) is a major building renovation project in which site energy use intensity (including plug loads) has been reduced by at least 50% from the pre-renovation baseline with a corresponding improvement in indoor environmental quality and comfort.

Core Technologies Bundle

Category	Name	Specification
Building Envelope	Roof insulation	Level defined through modeling
	Wall insulation	Level defined through modeling
	Slab Insulation	Level defined through modeling
	Windows	Parameters defined through modeling
	Doors	National Standards
	Thermal bridges remediation	Guide, main text and Appendix D
	Air tightness	0.15 cfm/ft2 (for USA)
	Vapor Control	Guide, main text
	QA	Guide, Appendix J
Lighting and Electrical Systems	Lighting design , technologies and controls	Guide, Appendix G
	Advanced plug loads, smart power strips and process equipment	TopTen (Europe), Top Tier EnergyStar, FEMP Designated, etc
HVAC	High performance motors, fans, furnaces, chillers, boilers, etc	ASHRAE Std 90.1 2013 and EPBD
	DOAS	Guide, main text
	HR (dry and wet)	Guide, main text
	Duct insulation	EPBD requirements
	Duct airtightness	ASHRAE Handbook and EPBD requirements (Class C ductwork)
	Pipe insulation	EPBD requirements

Building Models Used by the Annex 61 Modeling Team

Austria, AEE 	**China, Chongqing University** 	**Denmark, Building Research Institute, SBi** 	**Estonia, TTU** 	**Germany, KEA Germany, PHI** 
Dormitory, c.z. 4A and 7	Office building, c.z. 2a, 3a, 3c, 4a, 7	School Building, c.z. 5A	Public housing, c.z. 6A	Office Building, c.z. 5A
Latvia, RTU 	UK, University of Reading 	U.S.A. ERDC-CERL 	U.S.A., ERDC-CERL 	U.S.A., ME Group 
Dormitory, c.z. 6A	Administrative, Building, c.z. 4A, 5A	Barracks, c.z. 1-8	Office Building, c.z. 1-8	Dormitory, c.z. 5B

Results are documented in five Technical papers presented and published in 2015-2016 by the ASHRAE and CLIMA 2016 conference (available at www.iea-annex61.org)

Modelled Scenarios

- Scenario 1 - Baseline: pre-1980 standard to describe the building envelope and systems. Building use and systems operation schedules as well as appliances and their use in W/m2, used in Scenario 1 have been kept the same for all scenarios, though it is likely that they will be improved/reduced over time;
- Scenario 2 – Business as usual (the base case) – building improvement to meet minimum current standards (usually related to energy efficiency of fans, motors, chillers, furnaces, lighting fixtures, etc).
- Scenario 3 – Optimize characteristics of the core technology bundle, which will result in 50% energy use reduction against the baseline or achieving current national minimum building energy use requirement for existing buildings
- Scenario 4 – Optimize characteristics of the core technology bundle to achieve the current national dream energy use intensity levels in the renovated building (e.g., passive house requirement).

Modeling Results: Wall Insulation

Country	U-value W/(m²*K) (Btu/(hr*ft²*°F)	R-value (m²*K)/W (hr*ft²*°F)/Btu
Austria (c.z. 5A) c.z.7	0.135 (0.024) 0.24 (0.043)	7.4. (42) 4.17 (23)
China c.z. 7 c.z. 4A c.z. 3A c.z. 2A c.z. 3C	0.31(0.054) 0.48(0.084) 0.60(0.106) 0.96(0.169) 0.96(0.169)	3.2(19) 2.1(12) 1.7(9) 1.0(6) 1.0(6)
Denmark (c.z. 5A)	0.15 (0.026)	6.7 (38)
Estonia (c.z. 6A)	0.17 (0.03)	5.9 (33)
Germany (c.z. 5A)	0.17(0.03)	4.2 (33)
Latvia (c.z. 6A)	0.19 (0.033)	5.3 (30)
UK (c.z. 4A) 5A	0.22(0.039) 0.22(0.039)	4.5(26) 4.5(26)
USA c.z. 1 c.z. 2 c.z. 3 c.z. 4 c.z. 5 c.z. 6 c.z. 7 c.z. 8	0.76 (0.133) 0.38 (0.067) 0.28 (0.050) 0.23 (0.040) 0.19 (0.033) 0.14 (0.025) 0.11 (0.020) 0.11 (0.020)	1.3 (8) 2.6. (15) 3.6 (20) 4.3 (25) 5.3. (30) 7.1. (40) 9.1 (50) 9.1 (50)

Site and Source Energy Use Reduction for DER Projects Using Core Bundles of Technologies and Beyond

Climate Zone	Baseline			Base Case		DER			HPB	
	Total site EUI (100%) kWh/m2yr (kBtu/ft2 yr)	Site EUI for heating (100%) kWh/m2 yr (kBtu/ft2 yr)	Source EUIt, (100%) kWh/m2 yr (kBtu/ft2 yr)	Site energy use reduction, %	Source energy reduction ,%	Site energy use reduction,%	Site heating energy use reduction, %	Source energy use reduction, %	Site energy use reduction, %	Source energy reduction, %
Public Housing, Austria										
5A	218 (69)	152 (48)	210 (67)	38	31	**50**	73	64	55	68
7	253 (80)	184 (58)	235 (75)	47	36	**50**	68	62	55	68
Office Building, China										
2A	3(1)	105(33)	331(105)	37	37	**47**	56	47	54	54
3A	25(8)	119(38)	378(120)	38	38	**51**	62	51	65	65
3C	8(3)	77(24)	243(77)	36	36	**47**	64	47	69	69
4A	117(37)	201(64)	393(125)	42	42	**53**	71	41	62	55
7	239(76)	306(97)	472(150)	32	33	**50**	62	38	67	59
School Building, Denmark										
6A	252 (80)	210 (67)	314 (99)	19	16	**56**	67	45	82	63
Dormitory, Estonia										
6A	153 (49)	213 (68)	225 (71)	29	22	**47**	69	37	70	58
Office Building, Germany										
5A	256 (81)	220 (70)	307 (97)	40	27	**55**	58	53	81	76
Office Building, UK										
4A	89(28)	155(49)	291(92)	20	16	**51**	84	32	58	42
5A	135(43)	201(64)	341(108)	23	20	**60**	83	42	67	52

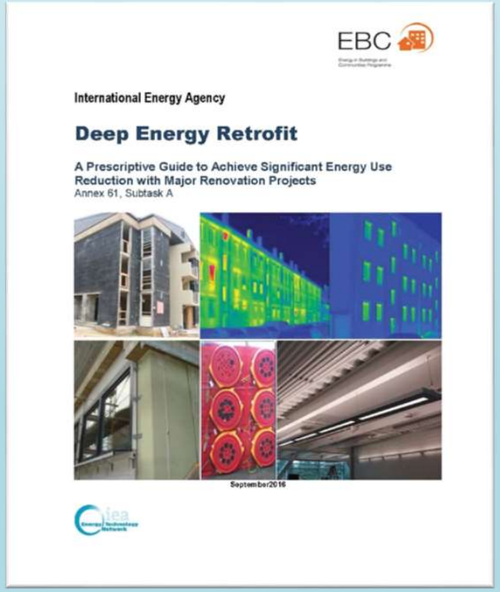
DER of Dining Facilities Vs. HPB Renovation (with an improvement of internal processes)

Climate Zone	Baseline			Base Case		DER			HPB	
	Site EUIh kWh/m² yr (kBtu/sq ft yr)	Site EUIt kWh/m² yr (kBtu/sq ft yr)	Source EUIt kWh/m² yr (kBtu/sq ft yr)	**Site Energy %**	Source Energy %	**Site Energy %**	Site Heating Energy %	Source Energy %	**Site Energy %**	Source Energy %
1A	29 (9,198)	604 (191)	1616 (512)	**2%**	3%	**15%**	29%	16%	**40%**	40%
2A	147 (46,626)	706 (224)	1687 (535)	**11%**	9%	**22%**	45%	20%	**48%**	36%
2B	111 (35,208)	744 (236)	1897 (601)	**10%**	9%	**22%**	43%	22%	**50%**	40%
3A	307 (97,377)	840 (266)	1766 (560)	**16%**	12%	**17%**	43%	23%	**57%**	45%
3B	201 (63,755)	749 (237)	1704 (540)	**16%**	12%	**26%**	52%	23%	**51%**	42%
3C	196 (62,169)	645 (205)	1371 (434)	**8%**	7%	**26%**	29%	14%	**46%**	32%
4A	459 (145,590)	964 (306)	1832 (581)	**20%**	15%	**30%**	47%	25%	**63%**	43%
4B	333 (105,624)	854 (271)	1753 (556)	**22%**	16%	**30%**	53%	25%	**58%**	45%
4C	434 (137,660)	897 (284)	1665 (528)	**19%**	14%	**27%**	43%	22%	**61%**	44%
5A	572 (181,432)	1071 (340)	1932 (612)	**19%**	17%	**31%**	45%	42%	**67%**	50%
5B	470 (149,079)	972 (308)	1833 (581)	**24%**	18%	**33%**	52%	23%	**64%**	48%
6A	733 (232,500)	1215 (385)	2041 (647)	**21%**	17%	**33%**	45%	28%	**71%**	54%
6B	681 (216,006)	1177 (373)	2035 (645)	**24%**	19%	**35%**	50%	29%	**69%**	53%
7	938 (297,524)	1420 (450)	2257 (715)	**22%**	19%	**36%**	47%	31%	**75%**	58%
8	1376 (436,453)	1863 (590)	2731 (866)	**18%**	17%	**39%**	64%	34%	**82%**	66%

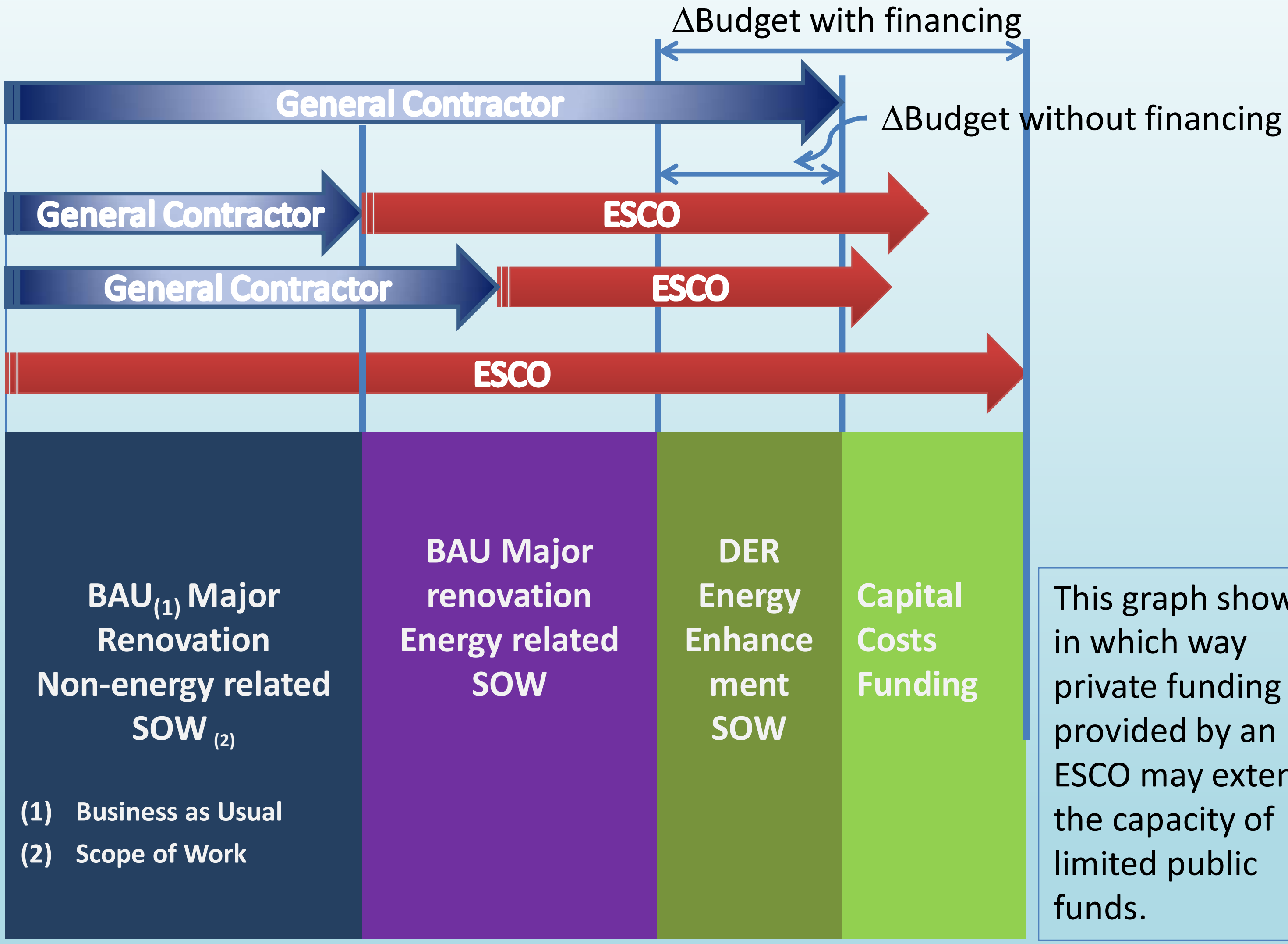
Dining Facilities compared to Barracks and Office Buildings have high ventilation, cooking, and sanitation loads, which make core envelope package much less effective.

DER Technical Guide Objectives

- Provide guidance on **core technologies bundle** for DER focusing on building envelope ECMs, lighting systems, HVAC systems efficiency
- **Technology Characteristics** (e.g., U-values, building and duct air tightness, illumination levels and LPD, etc.)
- **Critical design, construction requirements and recommendations** (how-to and how-not-to)
- **Important architectural details and pictures** for
  - Wall cross-sections
  - BE elements connections
  - Continuous air barrier
  - Vapor Control
  - Thermal bridge remediation
- **Outline Quality Assurance Process**
- **How to make DER Economics work?**



DER Implementation Strategies



This graph shows in which way private funding provided by an ESCO may extend the capacity of limited public funds.

Maximum (Cost Effective) Budget Increase for DER

$$\Delta \text{ Budget}_{max} = \text{NPV } [\Delta \text{ Energy (\$)}] + \text{NPV } [\Delta\text{Maintenance (\$)}] +$$
$$\text{NPV } [\Delta\text{Replacement Cost (\$)}] + \text{NPV } [\Delta\text{Lease Revenues (\$)}]$$

$$\Delta \text{ Budget}_{max} = SR_E \ [\Delta \text{ Energy (\$)}] + S_M \ [\Delta\text{Maintenance}] + S_L \ [\Delta\text{Lease Revenues}]$$

$$\text{NPV } [\Delta G \times C_G] = [\Delta G]_{t=1} \times C_{G(t=1)} \times (1+e)/d\text{-}e) \times [1\text{-} (1+e)/1+d)]^N = [\Delta G]_{t=1} \times C_{G(t=1)} \, S_E$$

S_M and S_L scalars can be calculated and are the uniform present worth factor series that use the discount rate, the same way as SR_E with the escalation rate e=0%.

NPV = Net Present Value function
N = study life in years
d = discount rate
e = escalation rate

Pilot Projects

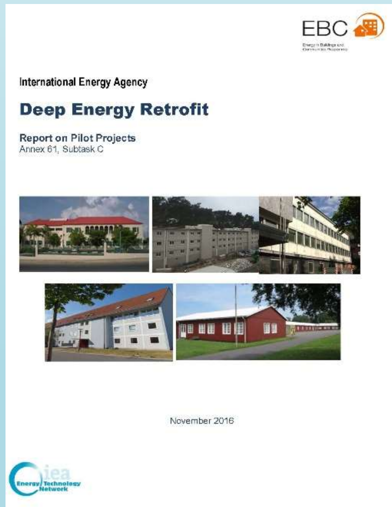
Federal building and courthouse in St. Croix, U.S. Virgin Islands

Presidio Military Barracks in Monterey, California, U.S.A.

IWU Office Building in Darmstadt, Germany

Dormitory in Manheim, Germany

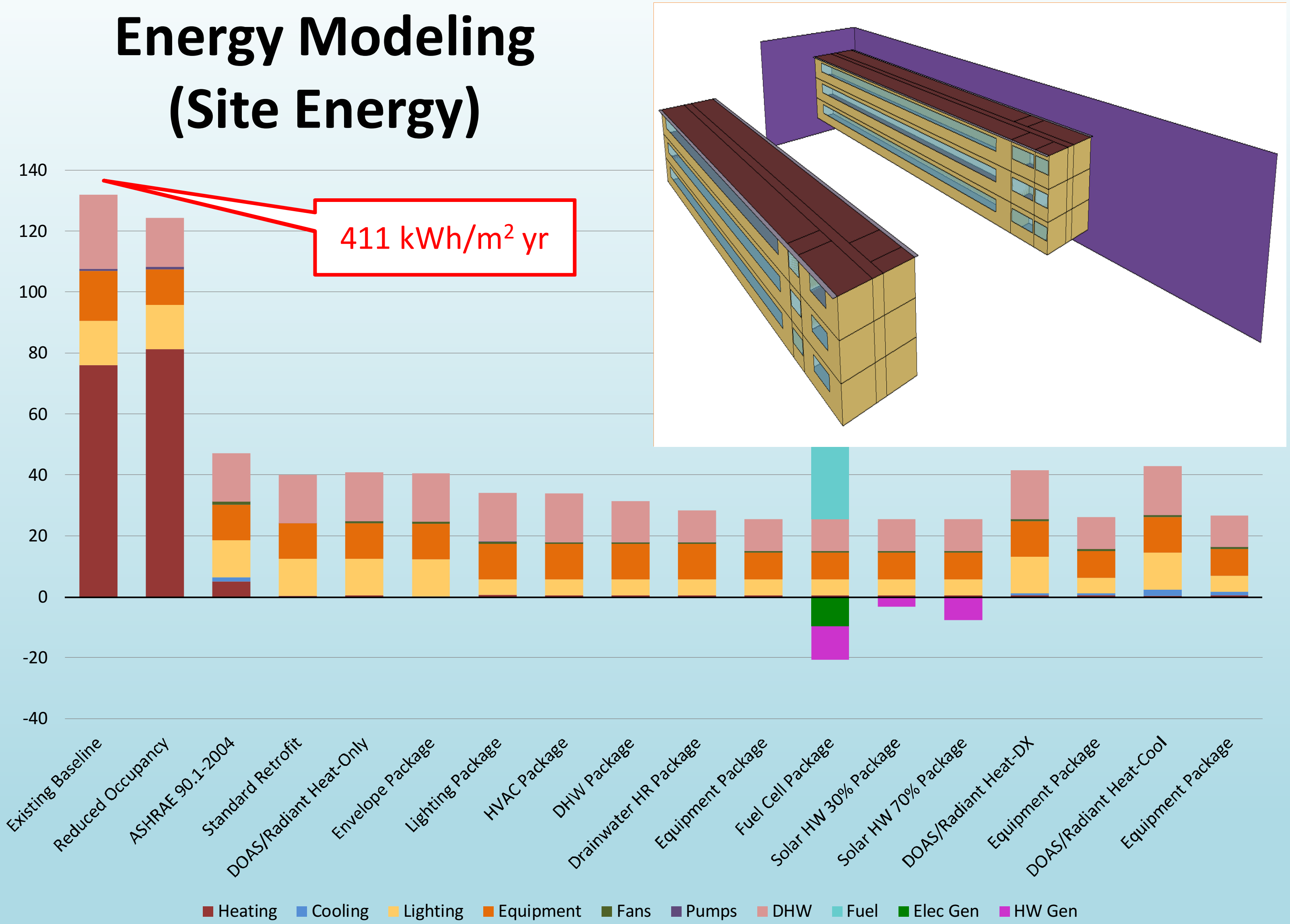
Almegårds Caserne Military Barracks in Bornholm, Denmark



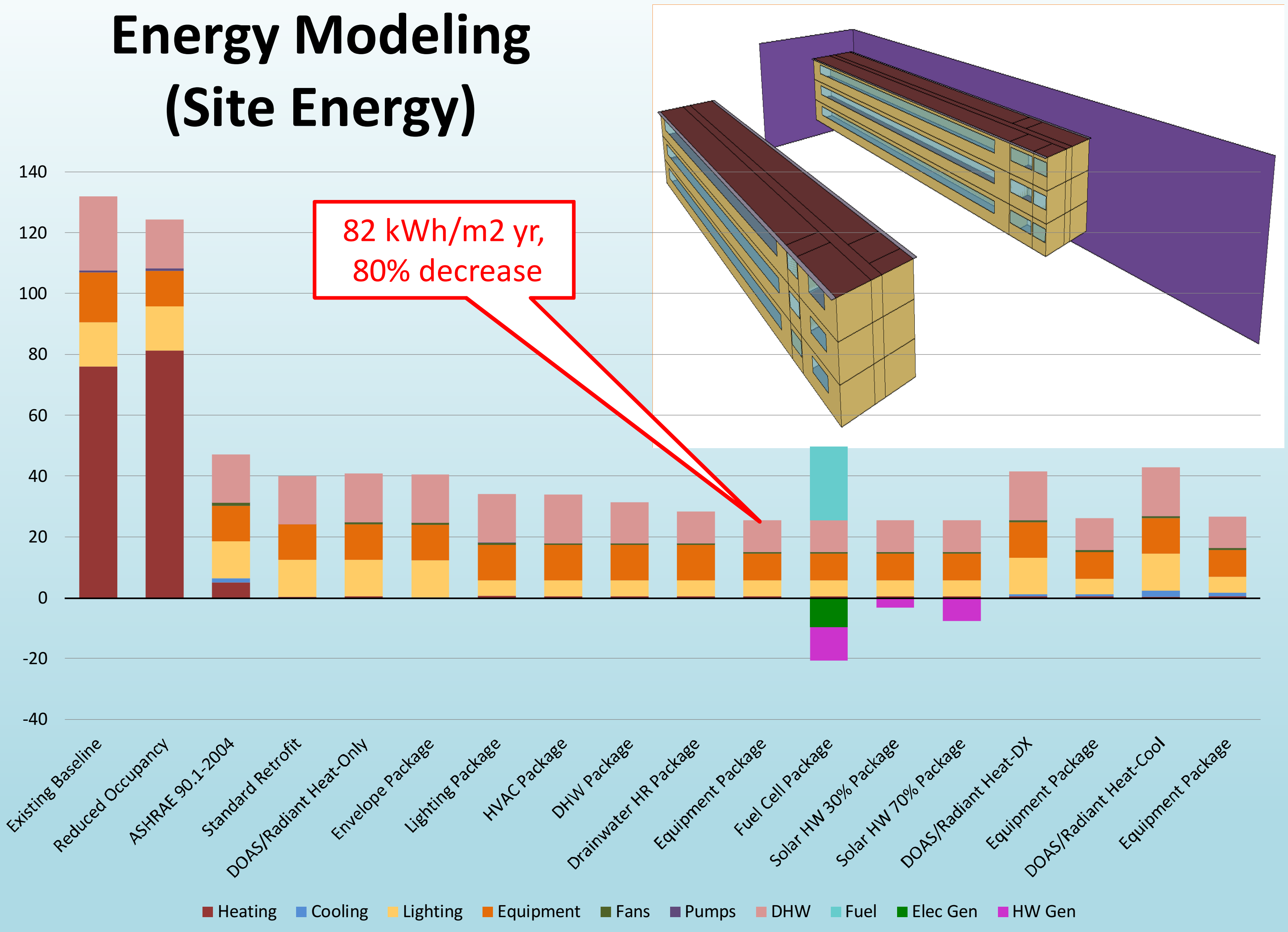
US Army Garrison, Presidio of Monterey

Barracks Prior to Renovation

Energy Modeling (Site Energy)



Energy Modeling (Site Energy)

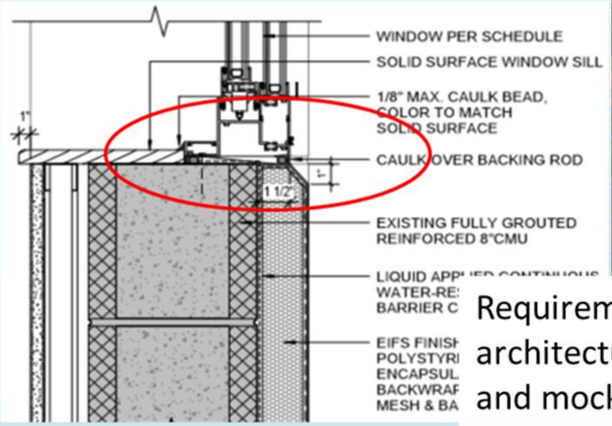


Barracks after Renovation

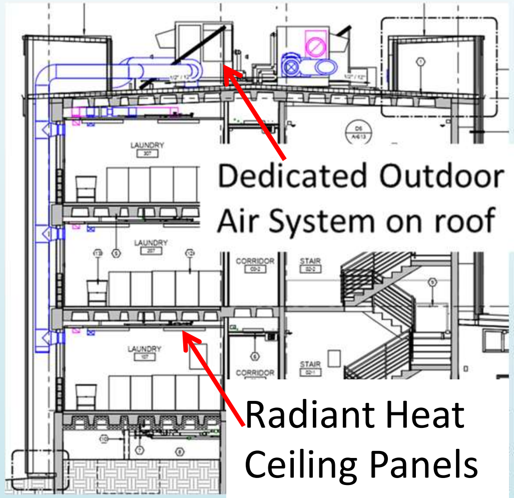
How do you reduce EUI by 80%?

- Continuous air and thermal barriers, better windows
- Dedicated outside air w/ heat recovery wheel
- Low-temperature radiant heating
- High efficiency boilers
- Advanced lighting systems and controls
- Grey water heat recovery on drain lines
- Solar Thermal for 70% of domestic hot water and heating load
- Quality Assurance process starting with the RFP

How do you reduce EUI by 80%? (Cont.)

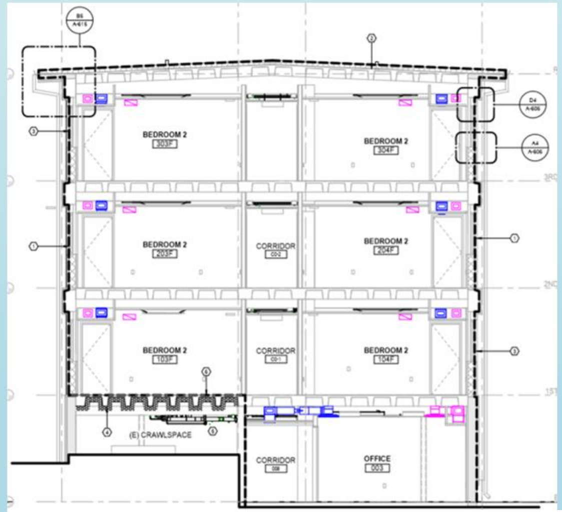


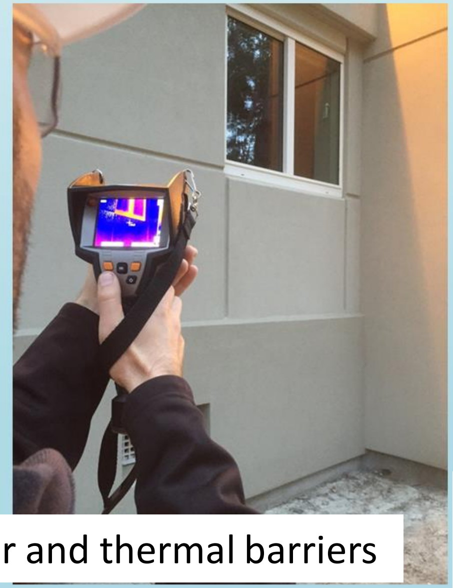
Requirement for architectural details and mock-ups



Dedicated Outdoor Air System on roof

Radiant Heat Ceiling Panels





Requirements for continuous air and thermal barriers

Improved IAQ with air ducts installed outside under insulation

Conclusions

- To meet long term energy goals, **major renovation** of buildings must be **combined with DER**, targeting at least 50% of building site energy use reduction
- This reduction in energy use can be achieved by implementing a **limited number of core technologies bundled together**
- **These technologies are readily available and** will be **cost effective as a bundle** if DER is timed as a part of a major building renovation that already has allocated funds including those required to meet minimum energy requirements.
- **Characteristics of these technologies vary country by country**: e.g., thickness of insulation, mass produced thermally broken window frames, length of anchors, etc. Governments **need to create the DEMAND** by specifying high performing technologies that will result in **product availability and lower prices** in THEIR MARKETPLACE": e.g., PV, triple-pane windows in Germany, airtight ductwork in Sweden, thick insulation in Denmark, high performance HR equipment in Scandinavia, LED, etc.

Conclusions (Cont.)

- End users, architects, construction companies, and ESCOs need to be **trained in specifying, designing, and applying the limited number of core technologies required for DER.**
- **QA process, starting with "Owners' Project Requirements" and RFP development and contracting, is essential** for DER and will minimize the cost of achieving energy and sustainability goals.
- Project evaluation for LCC effectiveness shall be conducted based on the bundle of EE technologies, not for each technology separately; non-energy related benefits of DER shall be accounted for (e.g., maintenance cost reduction, replacement cost reduction, building usable space increase, reduced absenteeism, space leas ability and rental rate increase, etc.)
- When DER is cost effective, additional funding can become available either from the government or public funds or from the private funding sources (using Energy Savings Performance Contract [ESPC] or Utility Energy Service Contract (UESC) models).

Questions?

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