U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Real life buildings striving to minimize life cycle impacts

Life-Cycle Energy & Related Impacts of Buildings Webinar Series

December 3, 2020

Agenda

I. **Opening Remarks**
   Marc LaFrance – Technology Manager, U.S. DOE Building Technologies Office

II. **Introduction to Life Cycle Carbon**
   Lyla Fadali – AAAS Policy Fellow, U.S. DOE Building Technologies Office

III. **Advancing a Net Zero Whole Life Carbon Vision**
   Victoria Burrows – Director of Advancing Net Zero, World Green Building Council

IV. **Embodied Carbon in LEED**
   Wes Sullens – Director of LEED, US Green Building Council

V. **Policy Recommendations for Procurement of Low Embodied Energy and Carbon Materials by Federal Agencies**
   Victor Olgyay – Buildings Principal, Rocky Mountain Institute

VI. **Energy Modeling, M&V, and Design Validation**
   Travis English – Director of Engineering, Chief Design Engineer, Kaiser Permanente

VII. **Q&A Session**
   Cedar Blazek – Management & Program Analyst, U.S. DOE Building Technologies Office

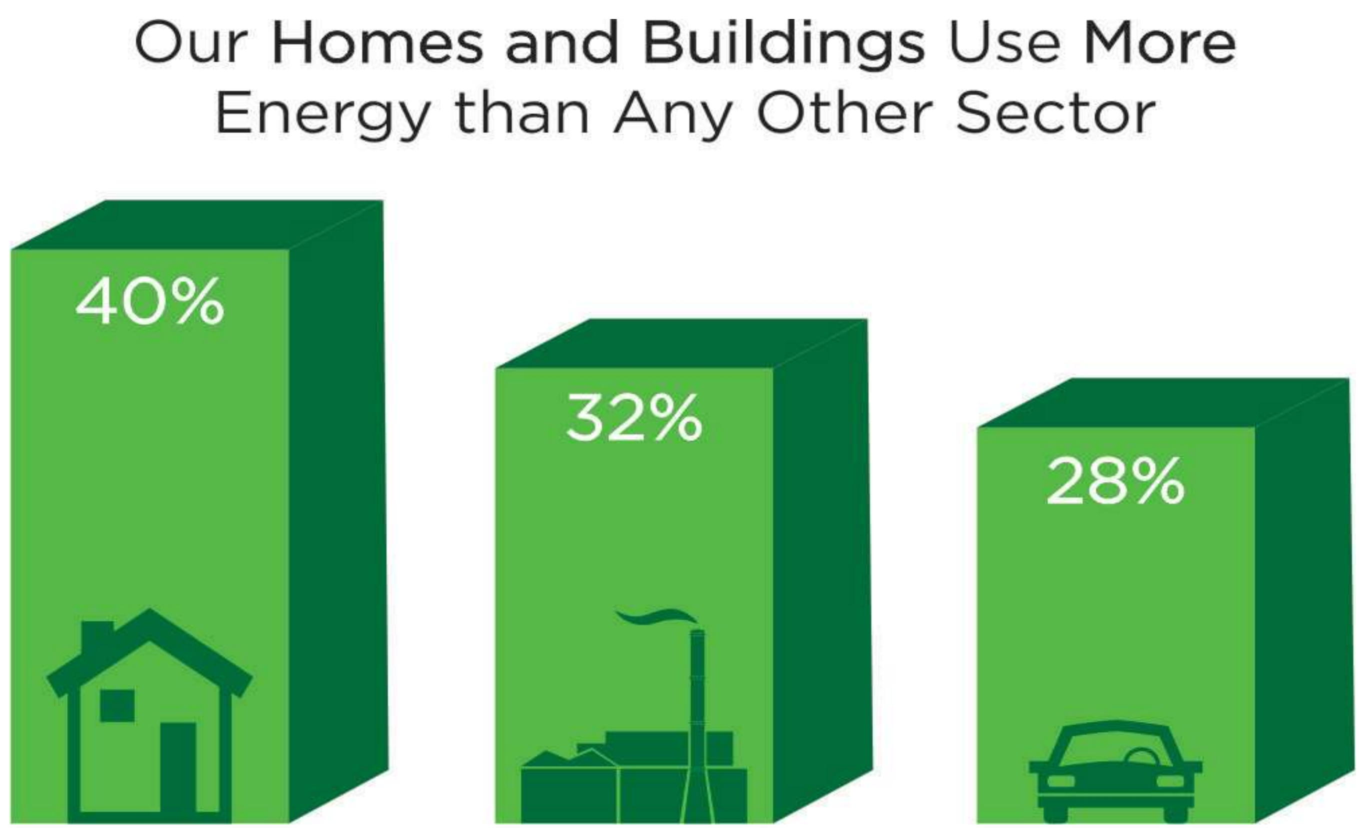
Building Life Cycle Impacts DOE Webinar Series

Topic	Date	Time
Overview of life cycle impacts of buildings	Oct. 16	12:00pm – 1:00pm ET
Challenges of assessing life cycle impacts of buildings	Oct. 29	12:00pm – 1:00pm ET
Innovative building materials	Nov. 12	12:00pm – 1:00pm ET
"Real Life" buildings striving to minimize life cycle impacts	Dec. 3	12:00pm – 1:00pm ET
Intersection of life cycle impacts & circular economy potential for the building sector	Dec. 17	12:00pm – 1:00pm ET

Poll Questions

- What industry are you from?
- What tools and other resources do you use for addressing life cycle impact decisions? Enter answers in the question box!

Efficiency is key to meeting U.S. energy goals



Residential & Commercial

Industrial

Transportation

Source: EIA Monthly Energy Review

Building Technologies Office

BTO invests in energy efficiency & related technologies that make homes and buildings more affordable and comfortable, and make the US more sustainable, secure and prosperous.

Budget ~US$285M/year; activities include:

R&D
Pre-competitive, early-stage investment in next-generation technologies

Integration
Technology validation, field & lab testing, metrics, market integration

Codes & Standards
Whole building & equipment standards technical analysis, test procedures, regulations

DOE research has saved energy and saved consumers money

FOR EXAMPLE:

Past

ENERGY STAR windows are common and can save up to $465 a year!

Present

- Double-pane & low-e
- Low heat loss
- 3x more efficient

Due to appliance standards alone, a typical household saves about $320 per year off their energy bills today.

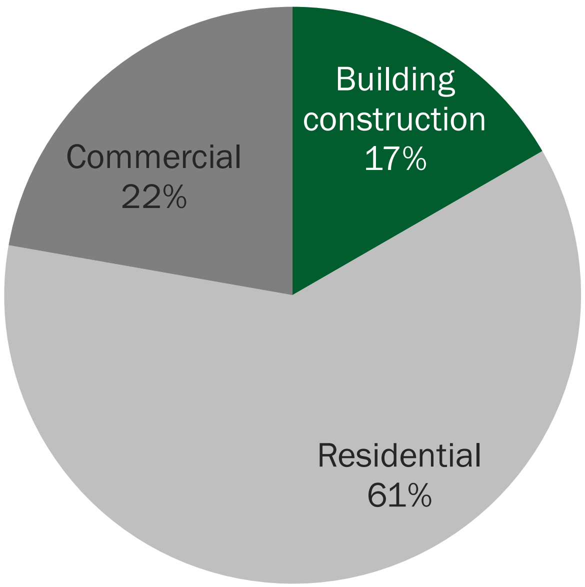
Our impact on a national scale

Energy efficiency standards completed through 2016 are expected to save **142 quadrillion Btu through 2030** — more energy than the entire nation consumes in one year.

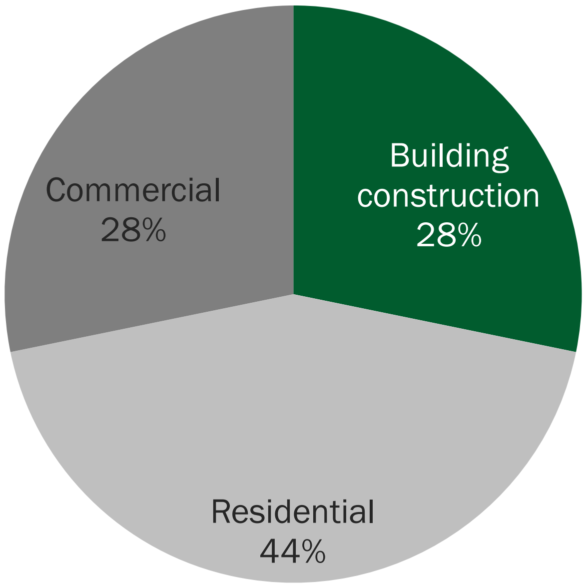
BTO’s work is making a difference, but we’re missing part of the picture.

Historically, BTO has focused on operating buildings.

Global energy use in buildings

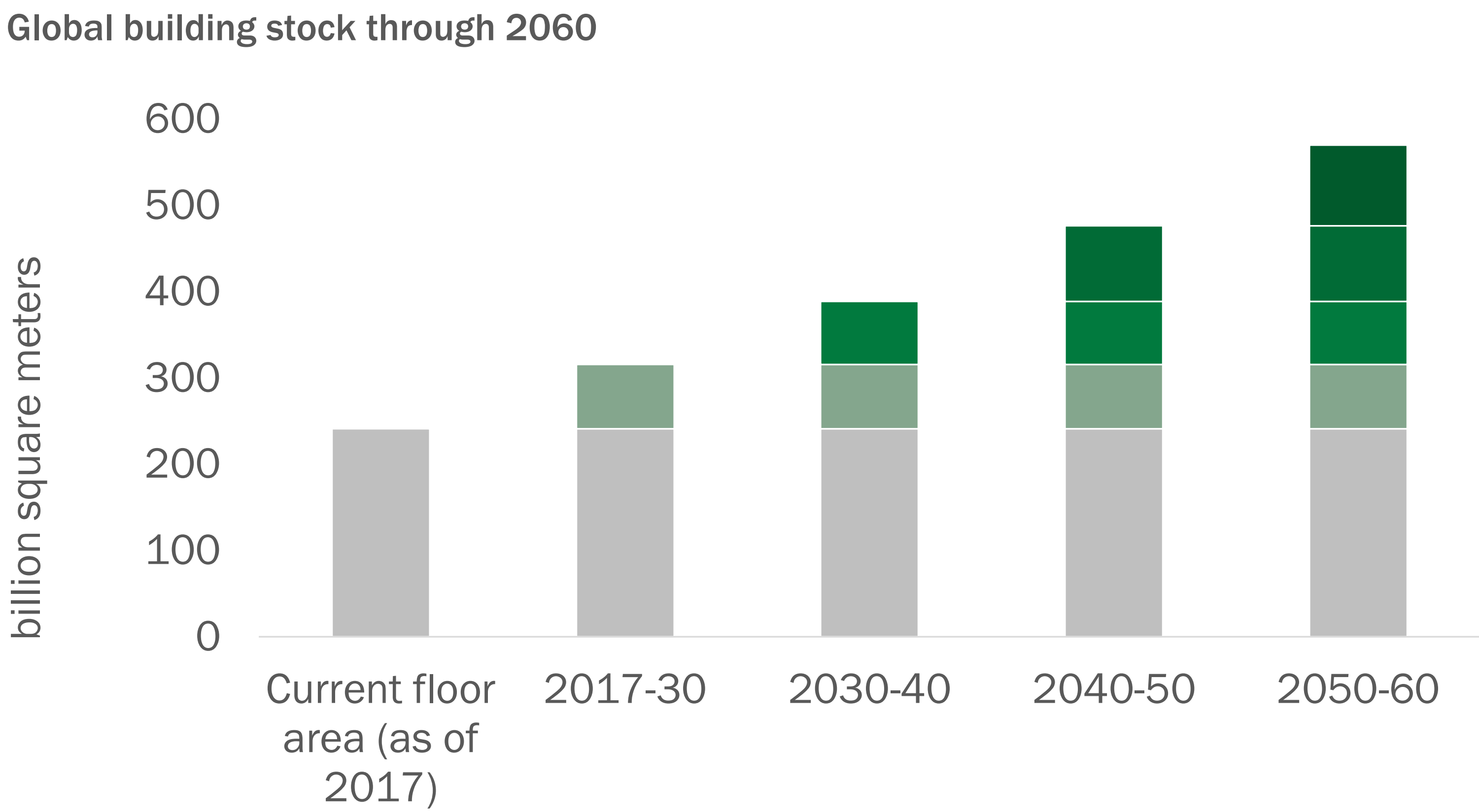


Global emissions from buildings



2018 Global Status Report. United Nations Environment Programme.
International Energy Agency for the Global Alliance for Building and Construction (GlobalABC)

Global building stock expected to more than double, making embodied carbon increasingly important.



Source data from GlobalABC Status Report in 2017

Let’s look at the whole picture:

Lifecycle carbon refers to carbon emissions associated with all stages of a building’s life

Resource extraction

Manufacturing

Transportation

Construction/ Installation

Equipment Replacement/ Maintenance

Operations

Demolition/ End of life

Embodied carbon is the carbon associated with all stages of a building’s life cycle not including operating the building

Operational carbon is the carbon associated with operating the building

What are the biggest opportunities? Where is BTO needed?

What can we do now?

Poll Question

What additional resources would be most helpful for life cycle impact decisions?

Enter answers in question box!

Advancing a Net Zero Whole Life Carbon Vision

Victoria Kate Burrows, Director, Advancing Net Zero

3 December 2020

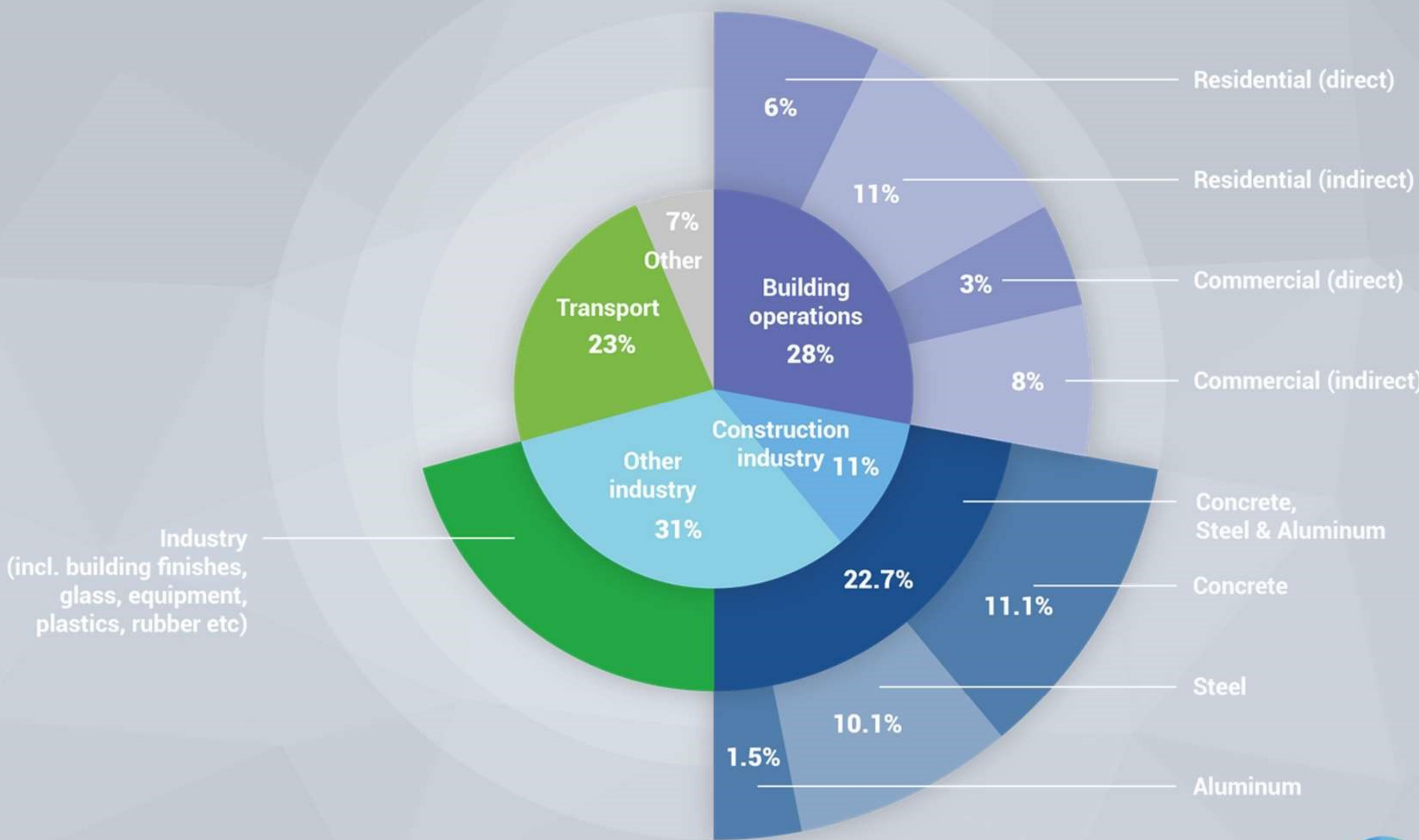
GLOBAL PROJECT FUNDERS

WE MEAN BUSINESS Kingspan SOM

ADVANCING NET ZERO

WORLD GREEN BUILDING COUNCIL

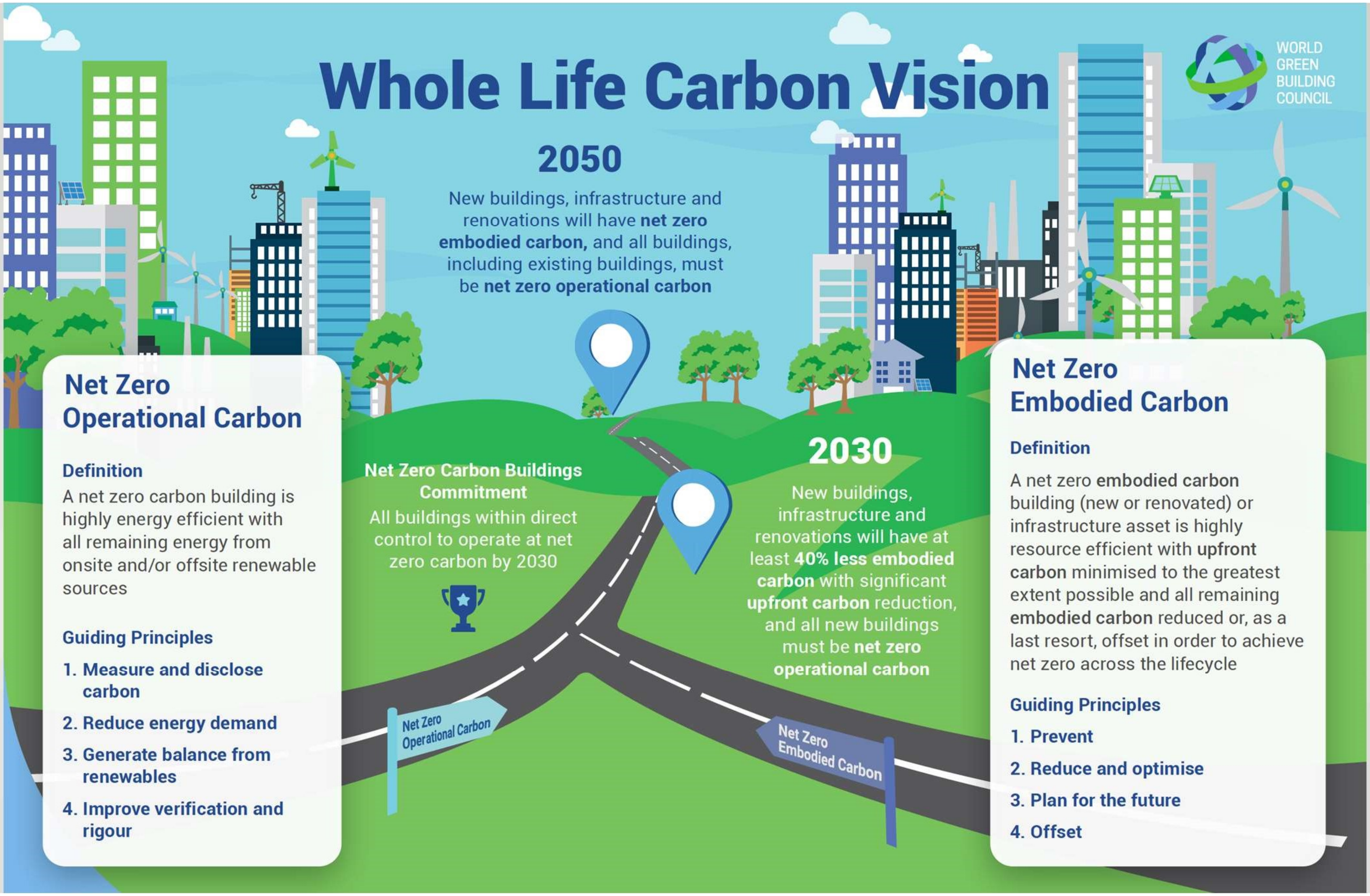
Sector Emissions



Source: IEA, GABC Status Report 2019, Architecture 2030

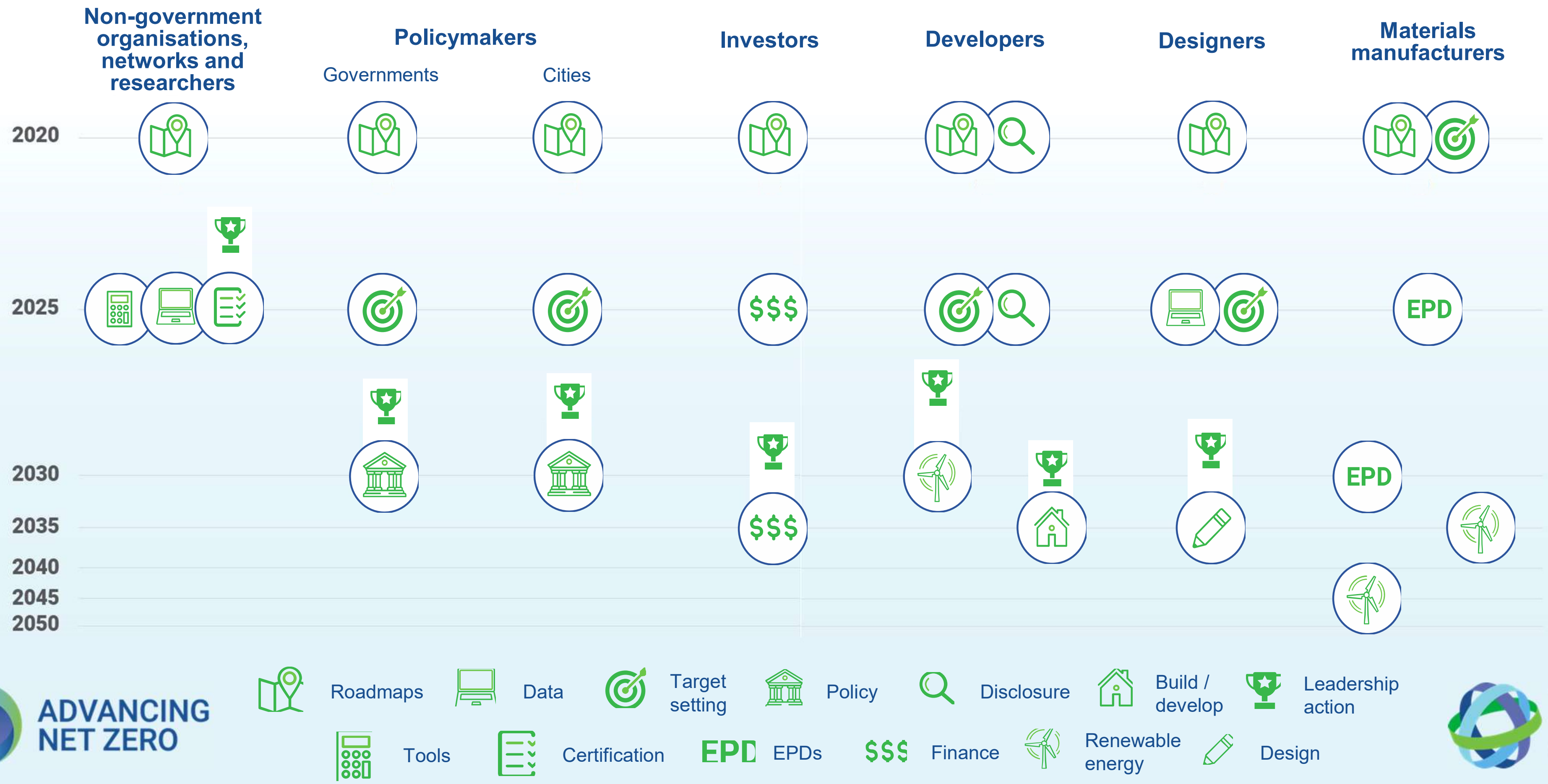
ADVANCING NET ZERO

WORLD GREEN BUILDING COUNCIL



Whole Life Carbon Vision
WORLD GREEN BUILDING COUNCIL
2050
New buildings, infrastructure and renovations will have **net zero embodied carbon,** and all buildings, including existing buildings, must be **net zero operational carbon**
Net Zero Operational Carbon
Definition
A net zero carbon building is highly energy efficient with all remaining energy from onsite and/or offsite renewable sources
Guiding Principles
1. Measure and disclose carbon
2. Reduce energy demand
3. Generate balance from renewables
4. Improve verification and rigour
Net Zero Carbon Buildings Commitment
All buildings within direct control to operate at net zero carbon by 2030
2030
New buildings, infrastructure and renovations will have at least **40% less embodied carbon** with significant **upfront carbon** reduction, and all new buildings must be **net zero operational carbon**
Net Zero Operational Carbon
Net Zero Embodied Carbon
Net Zero Embodied Carbon
Definition
A net zero **embodied carbon** building (new or renovated) or infrastructure asset is highly resource efficient with **upfront carbon** minimised to the greatest extent possible and all remaining **embodied carbon** reduced or, as a last resort, offset in order to achieve net zero across the lifecycle
Guiding Principles
1. Prevent
2. Reduce and optimise
3. Plan for the future
4. Offset

Summary of actions



ADVANCING NET ZERO

WORLD GREEN BUILDING COUNCIL

Thank you!

Victoria Kate Burrows

Director, Advancing Net Zero

vburrows@worldgbc.org

worldgbc.org/advancing-net-zero

GLOBAL PROJECT FUNDERS

Embodied Carbon in LEED

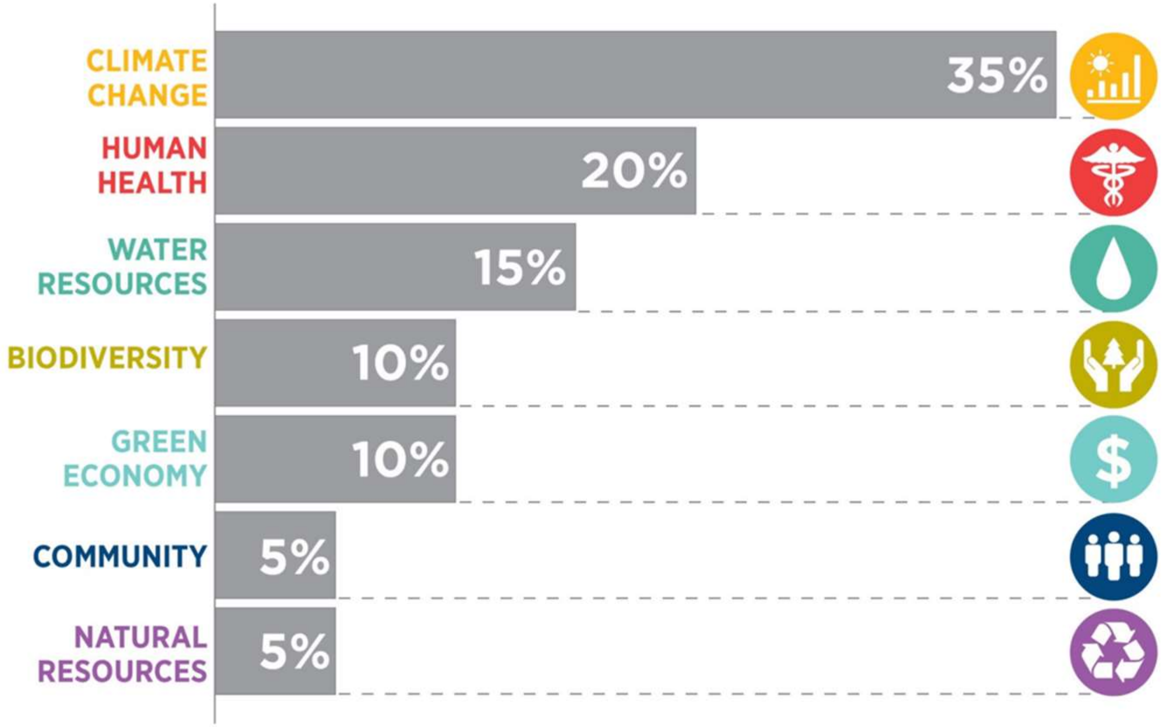
BTO Webinar Series on the Life-Cycle Energy: Innovative building materials

December 3, 2020

Wes Sullens Director, LEED U.S. Green Building Council


104,000
COMMERCIAL LEED PROJECTS
23 billion
TOTAL SQUARE FEET PARTICIPATING IN LEED
2.6 Million
CERTIFIED SQUARE FEET PER DAY
LEED PROJECTS ARE FOUND IN
180 countries & territories
LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN
LEED
1.6 million
RESIDENTIAL UNITS REGISTERED & CERTIFIED
203,000
TOTAL LEED PROFESSIONALS
U.S. GREEN BUILDING COUNCIL

LEED v4 SYSTEM GOALS



PRIORITY AREAS FOR MATERIALS & RESOURCES IN LEED v4.1

LOW-CARBON

- Reuse of Buildings and Materials
- Whole Building Lifecycle Analysis
- Environmental Product Declarations
- Optimized Low-Carbon Materials
- Bio-based & Sustainably Harvested

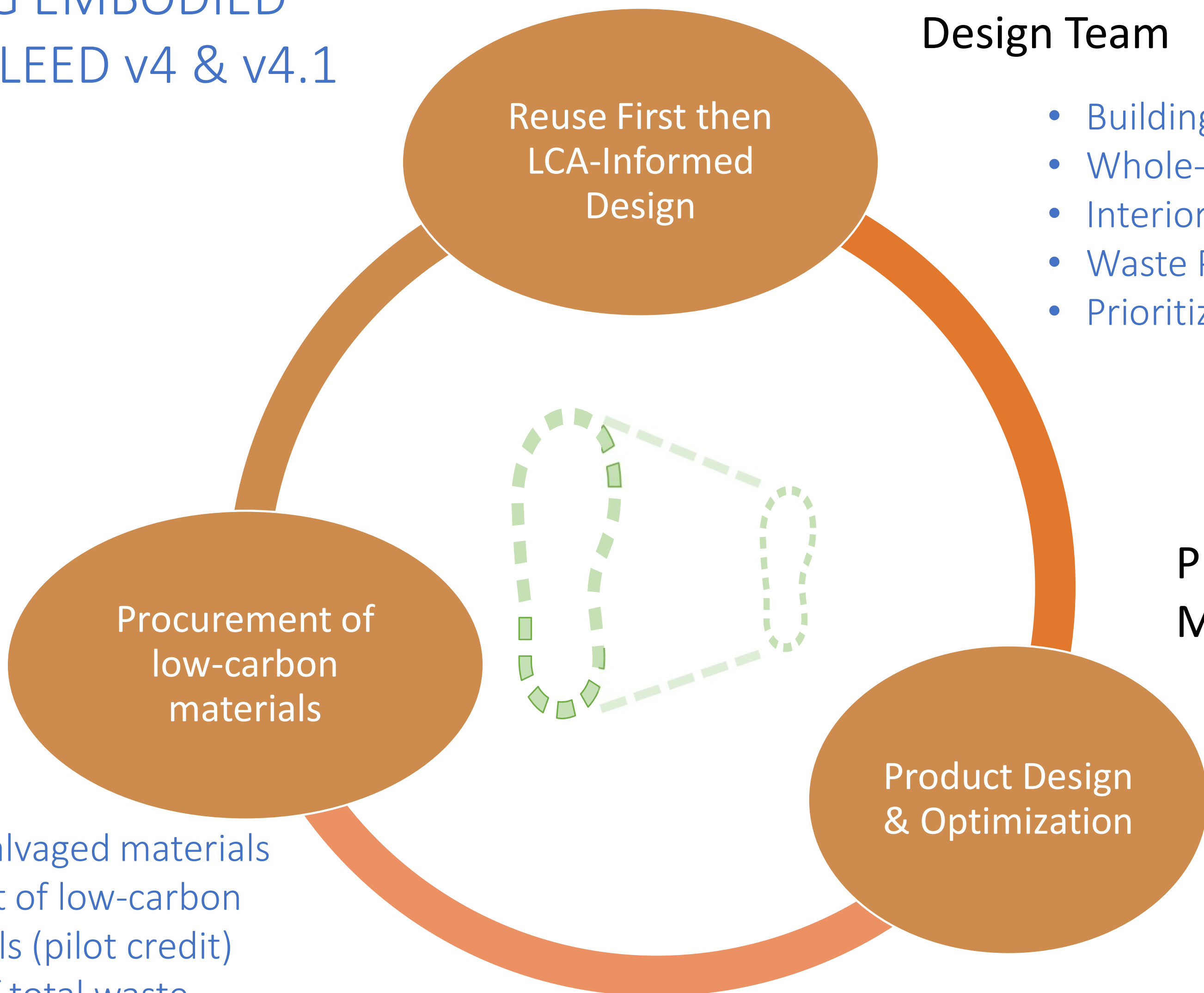
HEALTH

- Low-Emitting Materials
- Ingredient Disclosure
- Product Optimization
- Green Chemistry
- Supply Chain & Ecosystem

CIRCULAR

- Building Reuse & Salvage
- Recycling & Recycled Content
- Extended Producer Responsibility
- Zero Waste Manufacturing
- Bio-based & Sustainably Harvested

ADDRESSING EMBODIED CARBON IN LEED v4 & v4.1 CREDITS



Design Team

- Building & component reuse
- Whole-Building LCA
- Interiors LCA
- Waste Prevention
- Prioritize low-carbon materials

Product Manufacturers

- EPDs
- Renewable materials
- Recycled content
- Circular product design (pilot credit)

Construction Team

- Reuse and salvaged materials
- Procurement of low-carbon new materials (pilot credit)
- Reduction of total waste

THANK YOU!

Wes Sullens, LEED Fellow
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202-297-4229
Based in the Bay Area of California

U.S. Green Building Council
2101 L Street NW, Suite 500
Washington, DC 20037
Web: www.usgbc.org

Links & Resources:

- All-In: Creating a Safe & Equitable Future for All: www.usgbc.org/all-in
- LEED v4.1 for Buildings: new.usgbc.org/leed-v41
- November LEED v4.1 Addenda Update: www.usgbc.org/articles/leed-addenda-update-november-2020
- Circular Products Pilot Credit: www.usgbc.org/circularproductsv41
- Better Materials: https://bettermaterials.gbci.org/
- LEED Zero: https://www.usgbc.org/programs/leed-zero

Policy Recommendations for Procurement of Low Embodied Energy and Carbon Materials by Federal Agencies

Victor Olgyay, AIA
Rocky Mountain Institute

December 3rd, 2020

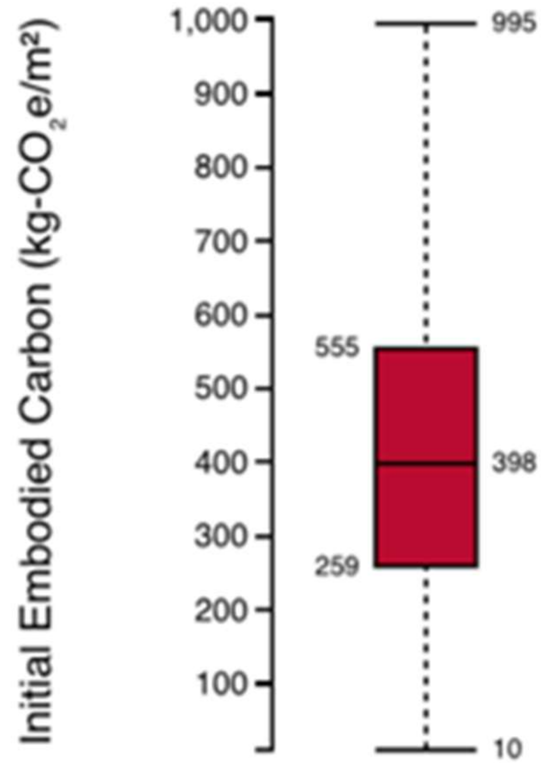
Embodied Energy Task Group Mission Statement

The Embodied Energy Task Group (EETG) is set up within the General Services Administration Green Building Advisory Council (GSA GBAC) to study the Federal energy, pollution, and cost savings that may be achieved by reducing the energy and carbon embodied in building construction.

Assuming the potential savings are significant, the EETG will produce relevant and readily adoptable procurement recommendations for the GSA to encourage the adoption of low embodied energy and carbon materials.

Anticipated reduction from baseline

- Accepted practice assumes that a 30% reduction from baseline can be typically achieved with zero to marginal cost increase
- Based on GSA's rate of construction this suggests roughly 633,000 metric tons CO_2e/year of reduction potential
- This would be equivalent to reducing GSA operational emissions by over 45%
- ***On average, per year, there were 44 projects completed, affecting 23M GSF, with a value of $1.03B.***



For commercial buildings, 60% fall within 555 kg-CO_2e/m^2 and 259 kg-CO_2e/m^2 with the average at 398. (CLF)

Key policy recommendation

Material approach

(for Below-Prospectus Projects and Tenant Improvements in Leased Space)

- Require environmental product declarations (EPDs) for the top 75% of materials used and ensuring they fall in the 80th percentile of global warming potential (GWP) as marked by industry averages.

Whole building life cycle assessment approach

(for Prospectus Projects)

- Design a building in such a way that results in a 20% reduction of GWP compared to a baseline building. Require this in addition to the already established requirements of the material approach.

Benefits from reducing embodied carbon

- Reduced supply chain energy costs
  - Estimated as $13 million per year
- Reduced air pollution
  - Estimated as to $12 million per year
- Reduced cost from more material-efficient designs
- Ease of regulatory compliance
- Mitigated climate change-related costs

Energy Modeling, M&V, and Design Validation

Speakers Travis English
Director of Engineering
Facilities Strategy Planning and Design
"Chief Design Engineer"

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Owner Energy Modeling Requirements - 2012

- Started in 2012
- 2012 Energy Targets for New Projects
- 2013 Life Cycle Cost Parameters
- "Energy calculations" incorporated into standard Professional Service Agreement (PSA) for design professionals on all projects

KAISER PERMANENTE
National Facilities Services
Facilities Planning and Design
Life Cycle Cost Parameters

LIFE CYCLE COST PARAMETERS

February 19, 2013
(updated:
Travis R. English, P.E.

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National Facilities Services
Facilities Planning
Energy Use Intensity Targets

NEW DESIGNS:

ENERGY USE INTENSITIY (EUI) TARGETS

August 27, 2012

Travis R. English, P.E.
Engineering Team Manager
NFS- Facilities Planning

Phone: 714-469-9553
E-mail: Travis.R.English@kp.org

Manager/Sponsor
Ignatius Tsang, AIA, NCARB
NFS- Facilities Planning
1800 Harrison, 19th Floor
Oakland, CA 94612

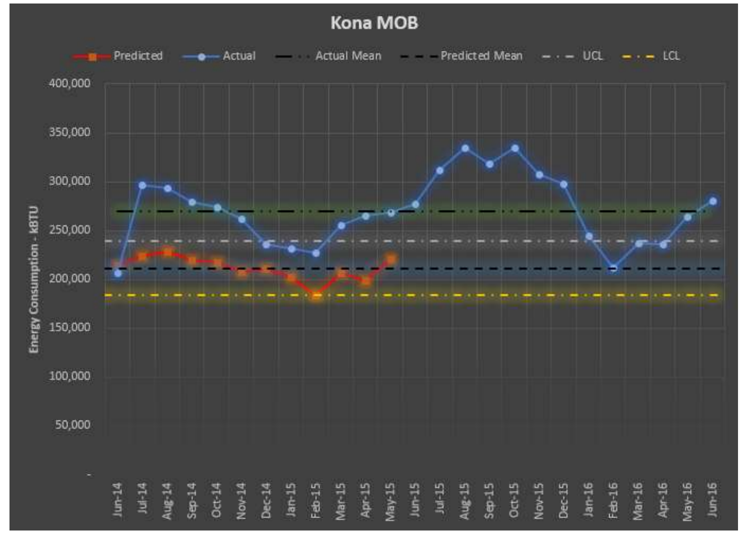
Phone: 510-625-2607
E-mail: Ignatius.X.Tsang@kp.org

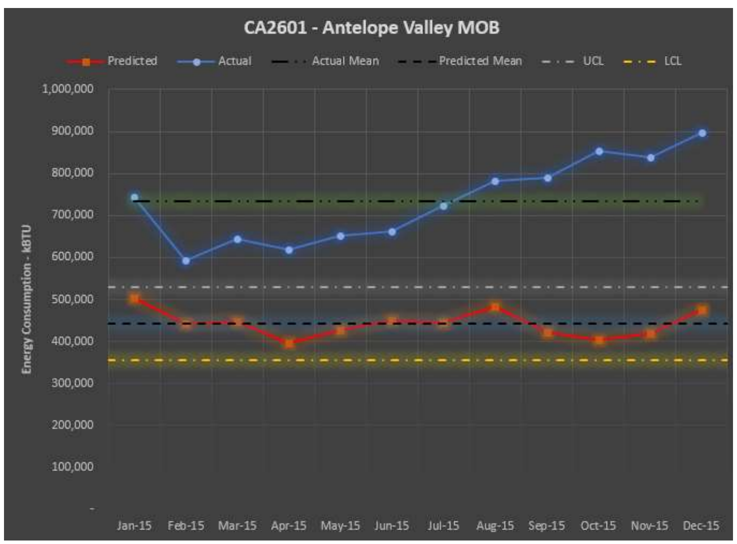
PURPOSE OF AN ENERGY USE INTENSITY (EUI) TARGET

Kaiser Permanente design criteria require projects to demonstrate at least a 25% margin over ASHRAE 90.1-2007. National energy benchmarking databases and tools use a metric called EUI. EUI stands for Energy Use Intensity. EUI is in units of kbtu per square foot per year. Projects'

Energy Modeling vs. Actual Performance 2017 Study (internal)

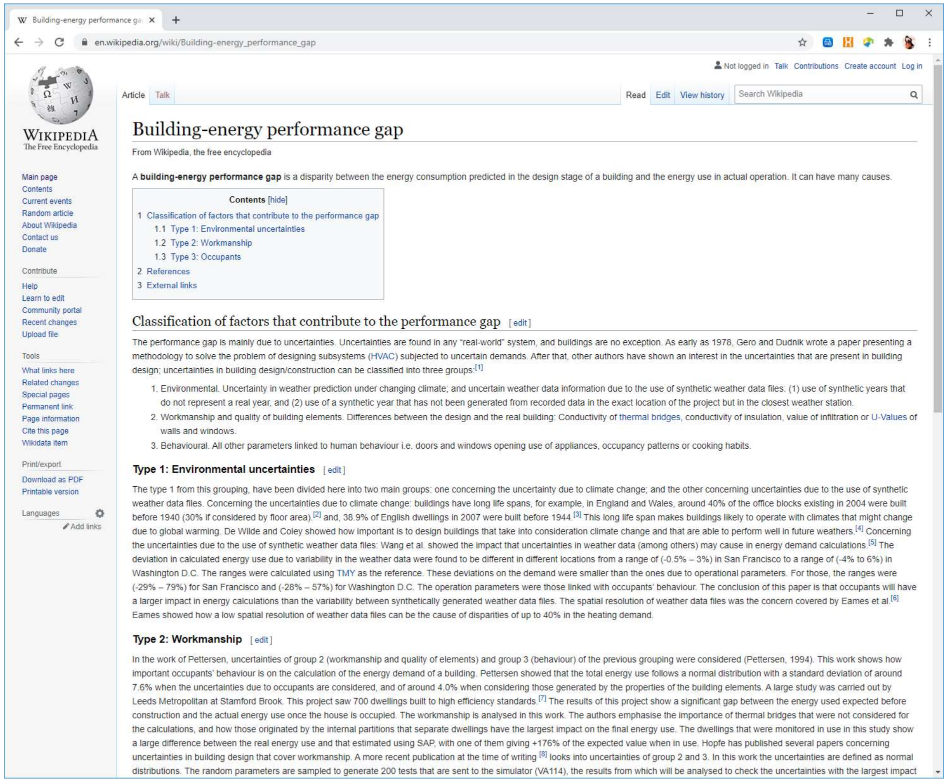
- Of 19 new building projects, actual ranges between *-19%* and *+158%* of design model.
- Average is *+50%*





Building-energy performance gap

- Variances in **operating hours**
- Variances in **occupancy**
- Variances in **weather**
- Variances in **lighting energy**
- Variances in **HVAC efficiency**
- Variances in **plug loads**
- Variances in **elevator, escalator**



en.wikipedia.org/wiki/Building-energy_performance_gap

Building-energy performance gap

From Wikipedia, the free encyclopedia

A **building-energy performance gap** is a disparity between the energy consumption predicted in the design stage of a building and the energy use in actual operation. It can have many causes.

Contents [hide]

Classification of factors that contribute to the performance gap [edit]

The performance gap is mainly due to uncertainties. Uncertainties are found in any "real-world" system, and buildings are no exception. As early as 1978, Gero and Dudnik wrote a paper presenting a methodology to solve the problem of designing subsystems (HVAC) subjected to uncertain demands. After that, other authors have shown an interest in the uncertainties that are present in building design; uncertainties in building design/construction can be classified into three groups:[1]

1. Environmental. Uncertainty in weather prediction under changing climate; and uncertain weather data information due to the use of synthetic weather data files: (1) use of synthetic years that do not represent a real year, and (2) use of a synthetic year that has not been generated from recorded data in the exact location of the project but in the closest weather station.
2. Workmanship and quality of building elements. Differences between the design and the real building: Conductivity of thermal bridges, conductivity of insulation, value of infiltration or U-Values of walls and windows.
3. Behavioural. All other parameters linked to human behaviour i.e. doors and windows opening use of appliances, occupancy patterns or cooking habits.

Type 1: Environmental uncertainties [edit]

The type 1 from this grouping, have been divided here into two main groups: one concerning the uncertainty due to climate change; and the other concerning uncertainties due to the use of synthetic weather data files. Concerning the uncertainties due to climate change: buildings have long life spans, for example, in England and Wales, around 40% of the office blocks existing in 2004 were built before 1940 (30% if considered by floor area).[2] and, 38.9% of English dwellings in 2007 were built before 1944.[3] This long life span makes buildings likely to operate with climates that might change due to global warming. De Wilde and Coley showed how important is to design buildings that take into consideration climate change and that are able to perform well in future weathers.[4] Concerning the uncertainties due to the use of synthetic weather data files: Wang et al. showed the impact that uncertainties in weather data (among others) may cause in energy demand calculations.[5] The deviation in calculated energy use due to variability in the weather data were found to be different in different locations from a range of (-0.5% – 3%) in San Francisco to a range of (-4% to 6%) in Washington D.C. The ranges were calculated using TMY as the reference. These deviations on the demand were smaller than the ones due to operational parameters. For those, the ranges were (-29% – 79%) for San Francisco and (-28% – 57%) for Washington D.C. The operation parameters were those linked with occupants' behaviour. The conclusion of this paper is that occupants will have a larger impact in energy calculations than the variability between synthetically generated weather data files. The spatial resolution of weather data files was the concern covered by Eames et al.[6] Eames showed how a low spatial resolution of weather data files can be the cause of disparities of up to 40% in the heating demand.

Type 2: Workmanship [edit]

In the work of Pettersen, uncertainties of group 2 (workmanship and quality of elements) and group 3 (behaviour) of the previous grouping were considered (Pettersen, 1994). This work shows how important occupants' behaviour is on the calculation of the energy demand of a building. Pettersen showed that the total energy use follows a normal distribution with a standard deviation of around 7.6% when the uncertainties due to occupants are considered, and of around 4.0% when considering those generated by the properties of the building elements. A large study was carried out by Leeds Metropolitan at Stamford Brook. This project saw 700 dwellings built to high efficiency standards.[7] The results of this project show a significant gap between the energy used expected before construction and the actual energy use once the house is occupied. The workmanship is analysed in this work. The authors emphasise the importance of thermal bridges that were not considered for the calculations, and how those originated by the internal partitions that separate dwellings have the largest impact on the final energy use. The dwellings that were monitored in use in this study show a large difference between the real energy use and that estimated using SAP, with one of them giving +176% of the expected value when in use. Hopfe has published several papers concerning uncertainties in building design that cover workmanship. A more recent publication at the time of writing [8] looks into uncertainties of group 2 and 3. In this work the uncertainties are defined as normal distributions. The random parameters are sampled to generate 200 tests that are sent to the simulator (VA114), the results from which will be analysed to check the uncertainties with the largest impact

Kaiser Energy Modeling Requirements – 2016 Update

- Margin of error : *"assume a minimum 10% in the non-beneficial direction"*
- Include ***"energy predications"***, not ***"output of an energy models"***

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National Facilities Services
Facilities Planning and Design

Life Cycle Cost Parameters

LIFE CYCLE COST PARAMETERS

February 19, 2013 Travis R. English, P.E.
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Facilities Planning and Design

Life Cycle Cost Parameters

ENERGY PREDICTIONS IN LCC ANALYSIS

LCCs should include an ***energy prediction***, not simply the output of an ***energy model***. While it is common practice in industry to use energy modeling for comparison purposes only, KP expects to realize the savings and values predicted in LCC analyses. Predictions should be risk-adjusted, and ready for validation.

Margin of Error

Experience on KP projects with calibrated energy models suggests a margin of error of 10-20%. If a calibrated model is used, the error of the model may be the error of the prediction. If there is no calibrated model, assume a minimum 10% error in the non-beneficial direction (less savings or more spending). Appropriately round results; do not present insignificant digits. (e.g. 521,237 kBtu, rounded to the nearest 5,000 = 530,000 kBtu)

Known Sources of Error

Energy predictions should accommodate known sources of error, including:

- Deviations between design weather and actual weather.
- Operating hours, including morning warm-up and cleaning crew hours.
- Deviations in equipment utilization (both additive and reductive).
- In-situ system or equipment performance versus manufacturers' stated efficiencies (e.g. lighting systems, fans, HVAC equipment efficiencies.)

Validation Readiness

Energy predictions should transfer directly to the project's measurement and verification plan (M&V Plan). Provide monthly predictions for each measured energy use.

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Example: 1-Year Calibration

Antelope Valley Medical Office Building

Summary of Energy Model Calibration Steps			
Modeled Variance		Real Variance	
Item	**Variance (MBTU)**	**Actual (Utility Bill) by Grouping**	**Variance (MBTU)**
Historical Weather	- 1%	Electricity (MBTU) • Model: 4,387 • Actual: 5,824	+33%
Interior Lighting	- 7%		
Exterior Lighting	4%		
Plug Loads	6%		
HVAC – Preheat Coil	1%		
HVAC – Zoning	- 0%		
HVAC – OA & RA Offset	- 1%		
HVAC – SAT Control	3%		
HVAC – Air Handlers	10%		
HVAC – Zone Airflows	9%	Natural Gas (MBTU) • Model: 934 • Actual: 2,859	+ 206%
Domestic HW	- 4%		
Solar HW System	5%		
Hot Water System	3%		
Unaccounted Natural Gas	17%	Difference:	+ 63%

Langran, Thomas and Weller, Michael. 2017. First Year Calibration of a Design Energy Model at a Medical Office Building. Presented at the 2017 ASHRAE Annual Conference, June 24-28.

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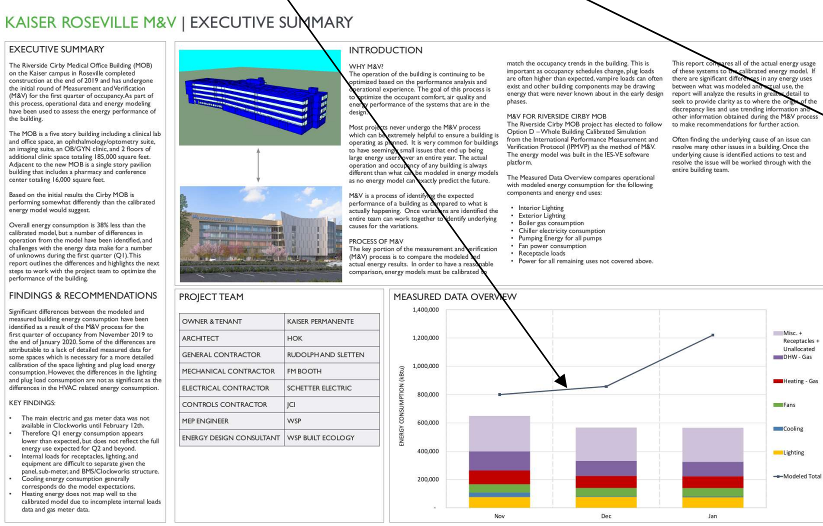
Recent Reports, Published in 2020

35% error

7% error

38% error


KAISER ROSEVILLE M&V | EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

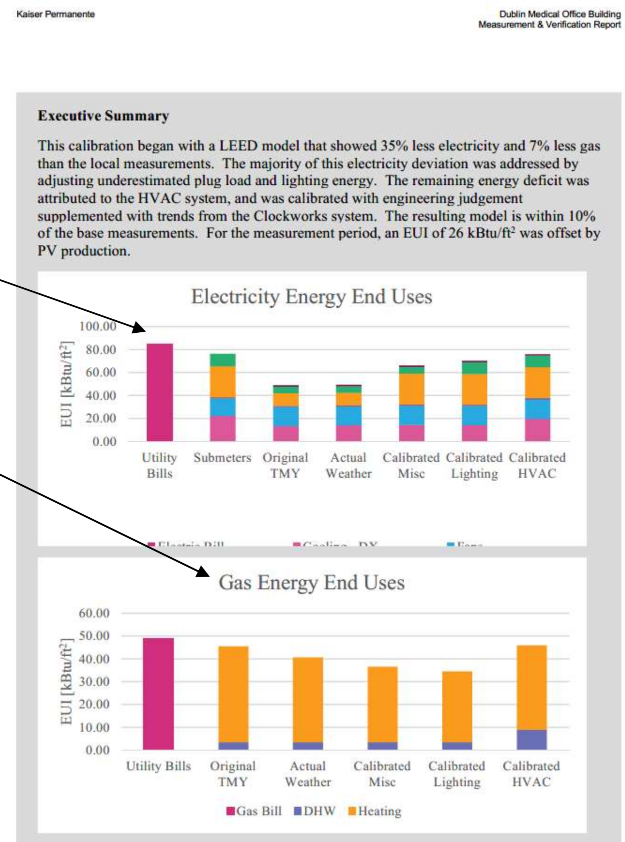
INTRODUCTION

FINDINGS & RECOMMENDATIONS

PROJECT TEAM

OWNER & TENANT	KAISER PERMANENTE
ARCHITECT	HOK
GENERAL CONTRACTOR	RUDOLPH AND SLETTEN
MECHANICAL CONTRACTOR	FM BOOTH
ELECTRICAL CONTRACTOR	SCHETTER ELECTRIC
CONTROLS CONTRACTOR	JCI
MEP ENGINEER	WSP
ENERGY DESIGN CONSULTANT	WSP BUILT ECOLOGY

MEASURED DATA OVERVIEW


Kaiser Permanente

Dublin Medical Office Building
Measurement & Verification Report

Executive Summary

This calibration began with a LEED model that showed 35% less electricity and 7% less gas than the local measurements. The majority of this electricity deviation was addressed by adjusting underestimated plug load and lighting energy. The remaining energy deficit was attributed to the HVAC system, and was calibrated with engineering judgement supplemented with trends from the Clockworks system. The resulting model is within 10% of the base measurements. For the measurement period, an EUI of 26 kBtu/ft² was offset by PV production.

What does 15%-20% margin of error mean?

C. ANALYSIS AND CALCULATION RESULTS

1. The following are the annual utility consumption and cost results based on energy type for each option:

Options	First Costs	Annual Electricity (kwh)	Annual Electricity Costs	Annual Natural Gas (therms)	Annual Natural Gas Costs	Annual O&M Costs	EUI (kbtu/sf/yr)
Option 1	$3,972,504	2,251,324	$255,114	24,954	$18,269	$27,545	366.6
Option 2	$4,059,924	2,111,494	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Option 3	$4,185,663	2,182,407					

Option 1, Constant Volume AHU's with R
standard design option for many healthcare
cost of the 3 options, mainly as a result of l

Option 2, Variable Air Volume AHU's with R
to pursue. Despite having an increased first
low annual energy cost provide enough sav

Option 3, 100% OSA Constant Volume AH
cost and maintenance costs relative to Opti

C. ANALYSIS AND CALCULATION RESULTS

1. The following are the annual utility consumption and cost results based on energy type for each option:

Options	First Costs	Annual Electricity (kwh)	Annual Electricity Costs	Annual Natural Gas (therms)	Annual Natural Gas Costs	Annual O&M Costs	EUI (kbtu/sf/yr)
Option 1	$3,505,985	1,764,715	$177,599	20,431	$15,132	$17,215	434.2
Option 2	$3,376,830	1,684,878	$171,887	20,500	$15,180	$17,215	419.9
Option 3	$3,505,758	1,66					
Option 4	$3,518,925	1,65					

Option 1 is considered the baseline s
facilities.

Option 2, 100% OSA Constant Volur
recommended option to pursue for t
immediate return on investment given

Option 4, 100% OSA Constant Volum
years and annual utility savings of $1
options, but only slightly higher than C
increase in first cost is able to be qui
option also gives it the lowest annual

Option 3, 100% OSA Variable Air Vol
its decreased first cost and energy co
Net Present Value. This is primarily a
difference in first cost when compared

C. ANALYSIS AND CALCULATION RESULTS

1. The following are the annual utility consumption and cost results based on energy type for each option:

Options	First Costs	Annual Electricity (kwh)	Annual Electricity Costs	Annual Natural Gas (therms)	Annual Natural Gas Costs	Annual O&M Costs	EUI (kbtu/sf/yr)
Option 1	$3,509,262	1,922,427	$192,523	55,897	$38,715	$22,714	728.5
Option 2	$3,583,522	1,715,5					
Option 3	$4,902,810	1,758,6					
Option 4	$5,209,496	1,728,5					
Option 5	$4,307,866	1,700,2					
Option 6	$3,781,430	1,715,5					

Option 1 provides the lowest first cost a
system for comparison purposes.

Option 2, dual Variable Air Volume Air H
recommended option to pursue for the
payback and annual utility savings of $4

Option 6, Variable Air Volume Air hand
years and annual utility savings of $46,2
generate additional energy savings ov
decreased maintenance costs, howeve
savings.

C. ANALYSIS AND CALCULATION RESULTS

1. The following are the annual utility consumption and cost results based on energy type for each option:

Options	First Costs	Annual Electricity (kwh)	Annual Electricity Costs	Annual Natural Gas (therms)	Annual Natural Gas Costs	Annual O&M Costs	EUI (kbtu/sf/yr)
Option 1	$798,000	2,604,870	$260,404	40,256	$28,885	$0	360.3
Option 2	$798,000	2,604,218	$260,292	40,539	$29,081	$0	360.9
Option 3	$798,000	2,610,242	$260,820	43,826	$31,362	$0	370.7
Option 4	$798,000	2,609,935	$260,756	44,773	$32,008	$0	373.3
Option 5	$764,750	2,582,518	$258,269	38,726	$27,824	$0	353.8
Option 6	$764,750	2,610,068	$260,788	44,335	$31,711	$0	372.1

Options 5 and 6, provide the lowest 1st cost. Option 5 however also results in the lowest life cycle cost and is the recommended envelope combination. Option 5 provides the lowest energy costs by balancing heating and cooling loads throughout the year. Both PPG Solarban 60 and Oldcastle Insulating Glass are equivalent glass types for the performance values indicate in Section A for Option 5.

Option 1 is the second recommended option as it results in the second lowest life cycle cost and second lowest EUI. The performance values of the selected glazing in Option 1 are similar to that of Option 5, however there are increased first costs for the View Dynamic Glass type.

Though maintenance costs for the glass type used in Option 5 have not been accounted, it is likely that some maintenance for this glass type should be anticipated given its low voltage component. The View Dynamic glass type is capable of tinting and lightening its color when a low voltage electric current is applied. The tinting and lightening occurs in response to outdoor conditions and can potentially allow this glass type to tailor its performance to outdoor conditions. However, due to shortcomings in software capabilities the View Dynamic glass was only simulated at a single performance point. Given the flexibility in performance of this glass type, it is possible that the life cycle cost of Option 1 may be less than or equal to Option 5.

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Q&A Session

- **Use the Q&A feature to ask a question**
- **Panelists**
  - Victoria Burrows – Director of Advancing Net Zero, World Green Building Council
  - Wes Sullens – Director of LEED, US Green Building Council
  - Victor Olgyay – Buildings Principal, Rocky Mountain Institute
  - Travis English – Director of Engineering, Chief Design Engineer, Kaiser Permanente

Building Life Cycle Impacts DOE Webinar Series

Topic	Date	Time
Overview of life cycle impacts of buildings	Oct. 16	12:00pm – 1:00pm ET
Challenges of assessing life cycle impacts of buildings	Oct. 29	12:00pm – 1:00pm ET
Innovative building materials	Nov. 12	12:00pm – 1:00pm ET
"Real Life" buildings striving to minimize life cycle impacts	Dec. 3	12:00pm – 1:00pm ET
Intersection of life cycle impacts & circular economy potential for the building sector	Dec. 17	12:00pm – 1:00pm ET