

Low-Carbon Housing Project

Speakers: Anika Huizinga, John Stehouwer, William Terpstra, Duncan Waanders

Engineering Seminar SB010 | December 1st, 2021

Presented by Engineering 333



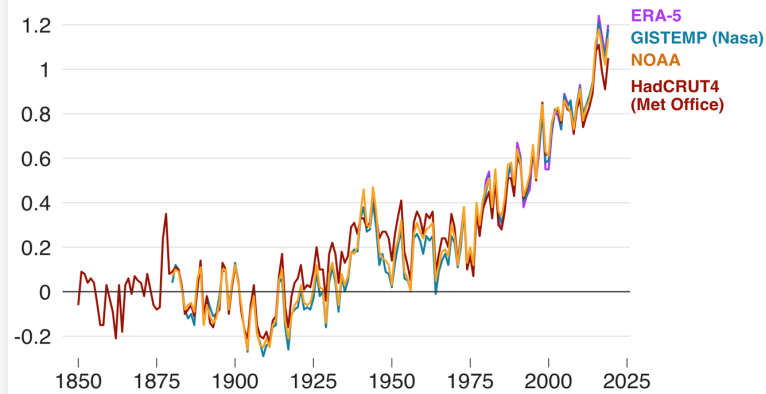
Outline

- Overview
- Teams
 - Embodied
 - Onsite
 - Utilities
 - Design
- Questions



Temperature rise since 1850

Global mean temperature change from pre-industrial levels, °C



Source: Met Office

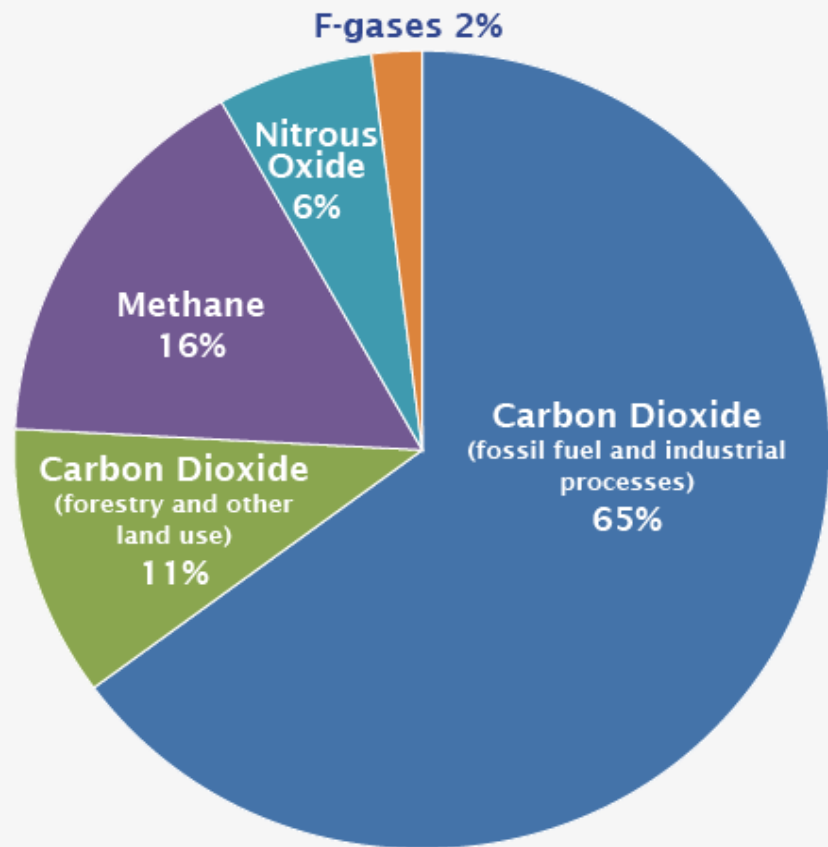
BBC



**UN CLIMATE
CHANGE
CONFERENCE
UK 2021**

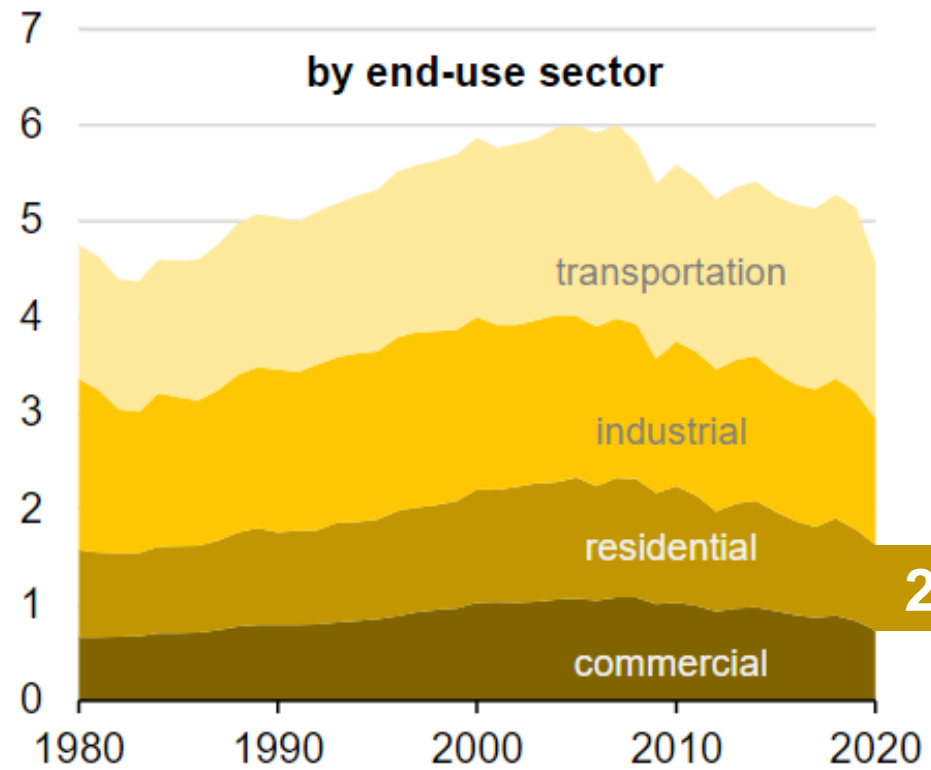
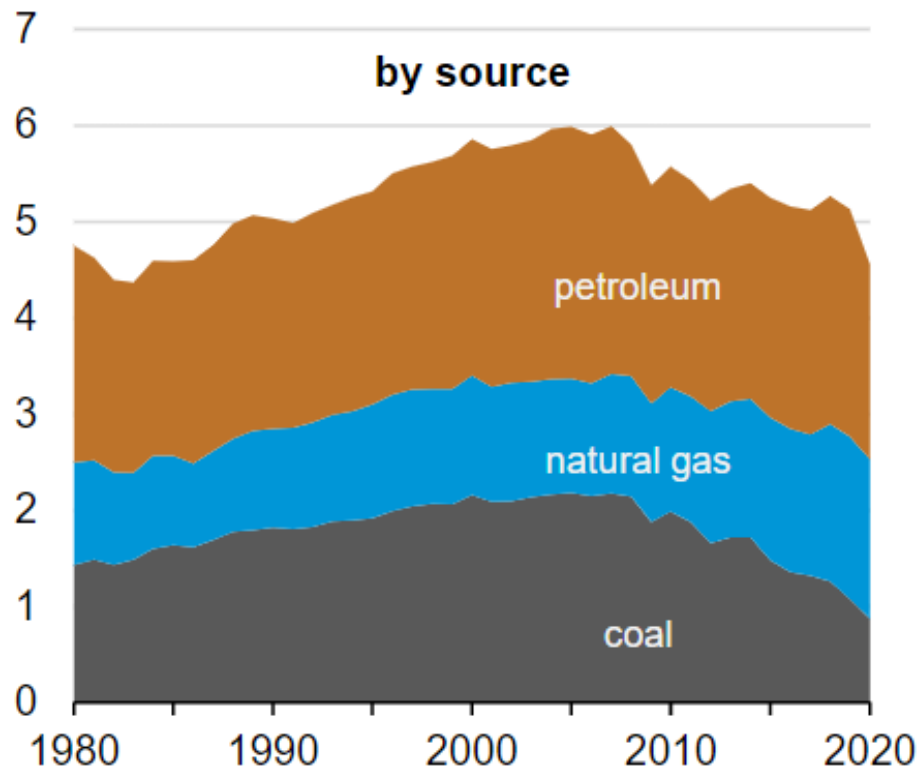
IN PARTNERSHIP WITH ITALY

Global Greenhouse Gas Emissions by Gas



U.S. energy-related carbon dioxide emissions (1980–2020)

billion metric tons





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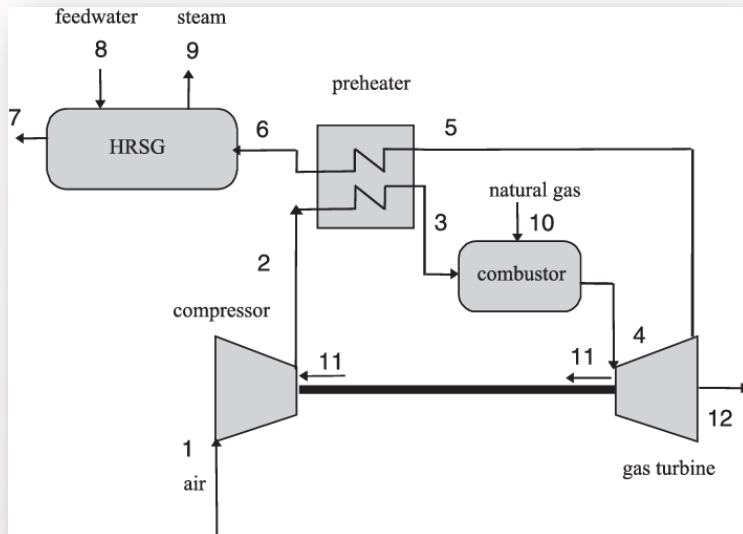
Kent County: ~400 Homes Built since 1983

National: ~350,000 Homes Built since 1976

Project Introduction – 08.31.2021

- What is the expected carbon emission savings of the carbon footprint house?
- If the carbon footprint build house is not carbon-neutral, how can carbon emissions be reduced by a further 20%?

Connections to Thermal Systems Design



- Heat Transfer
- Energy Usage
- Material Properties
- Specification Research
- Unit Continuity



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Sections



Section A

Case Study: 536 Stolpe St SW

Both Sections:

Low-Carbon Build: 726 London St SW



Section B

Case Study: 930 Woolsey Dr SW

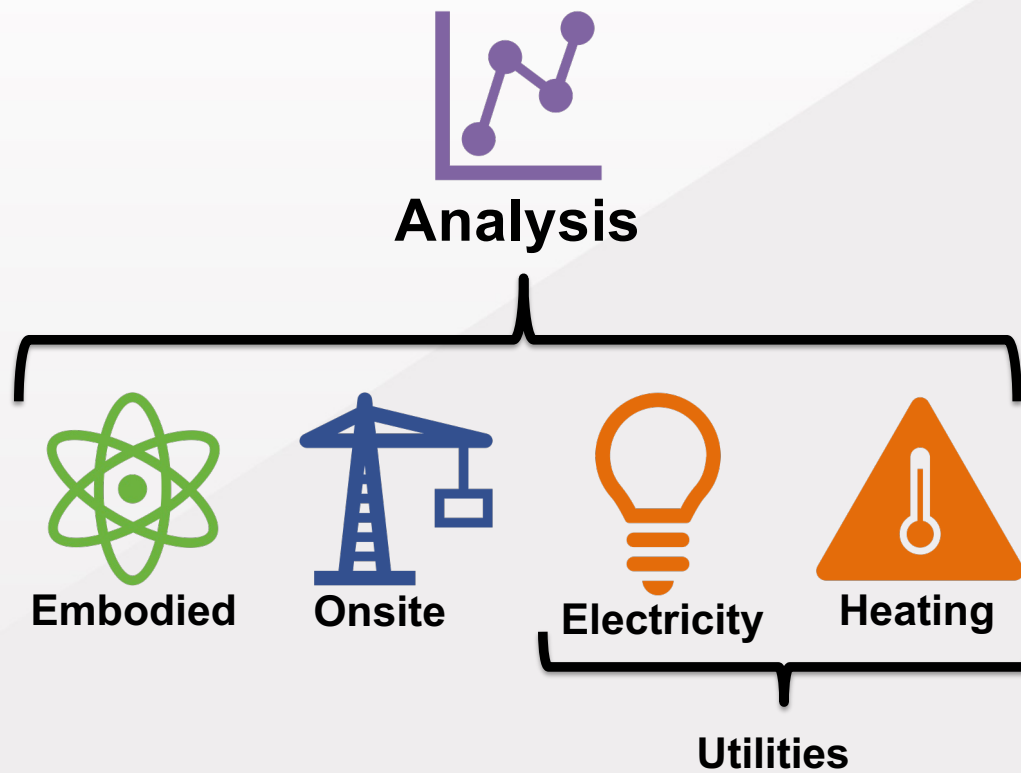


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Section Organization



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Progress Updates

- Status to Schedule
 - Work Accomplished
 - Issues / Concerns
 - Work Planned
-
- Each team member presented

Mark Ogland-Hand
(Client)



Professor Heun
(Consultant)



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OVERVIEW

EMBODIED

ONSITE

UTILITIES

DESIGN

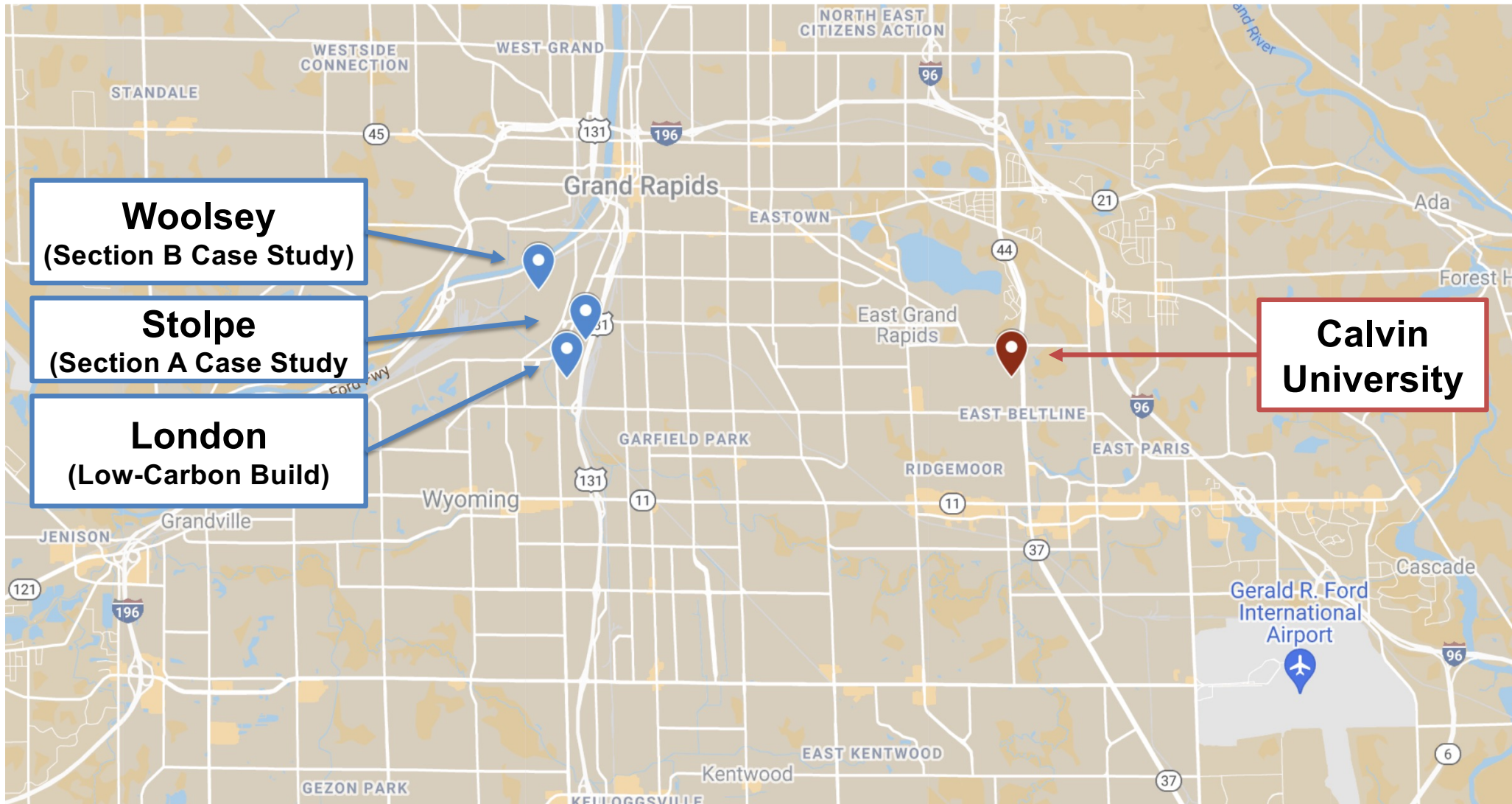
QUESTIONS

Woolsey
(Section B Case Study)

Stolpe
(Section A Case Study)

London
(Low-Carbon Build)

Calvin University



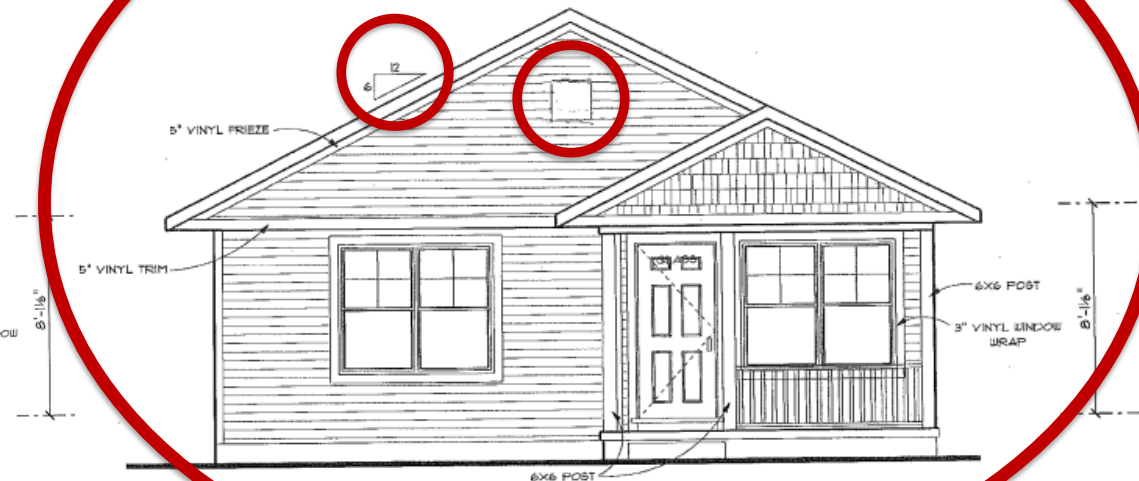
Team Differences

Section A 536 Stolpe Ave



~2019

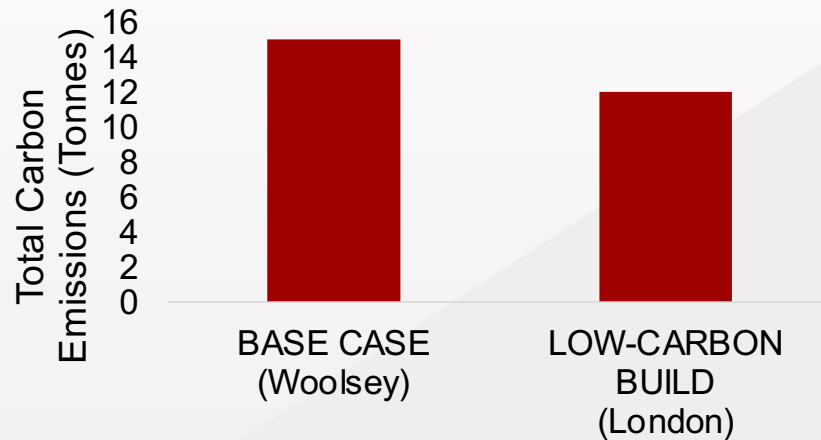
Section B 930 Woolsey SW



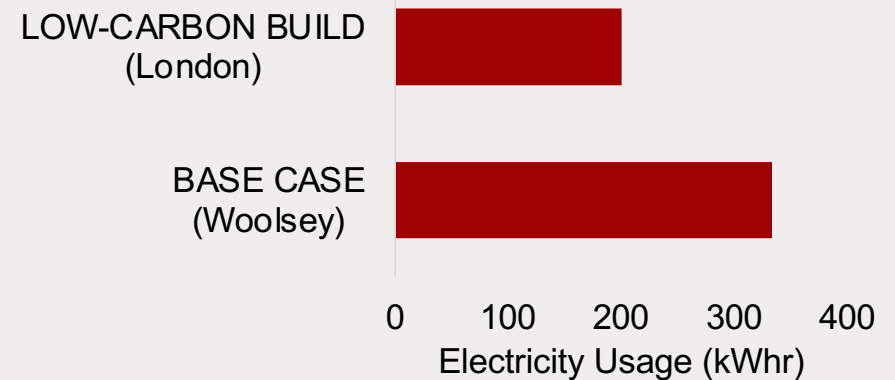
~2015

Note on Charts and Units

Vertical Bar Charts: Carbon Emissions



Horizontal Bar Charts: Usage Rates



Carbon Emission listed as Metric Tonnes

(1 Tonne = 1000 kg \neq 2000 lbs)



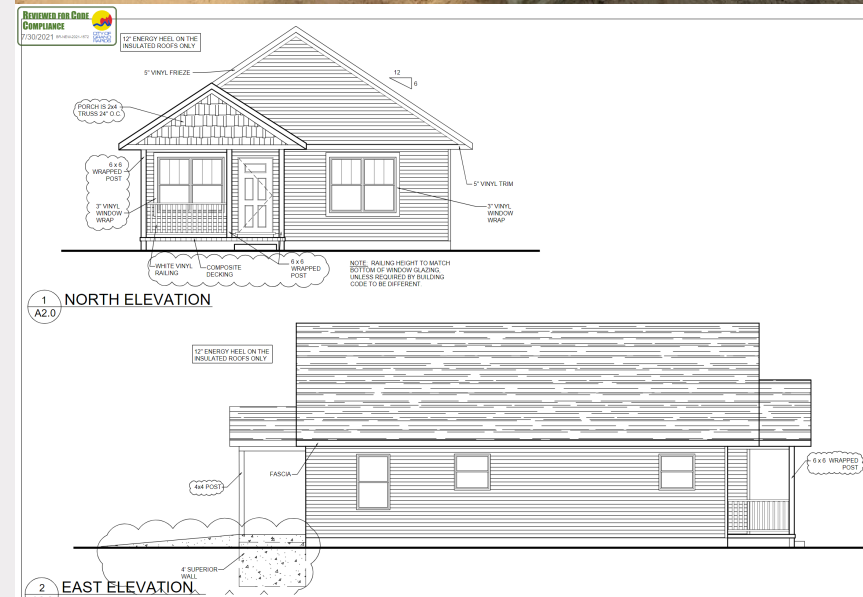
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London: Low-Carbon Build House

- **Insulated Concrete Forms Foundation**
 - **All Electric**
 - Heat pump
 - Water Heater
 - Other Appliances
- } Move Heat
(Rather than
Generate Heat)



OVERVIEW

EMBODIED

ONSITE

UTILITIES

DESIGN

QUESTIONS

London Progress



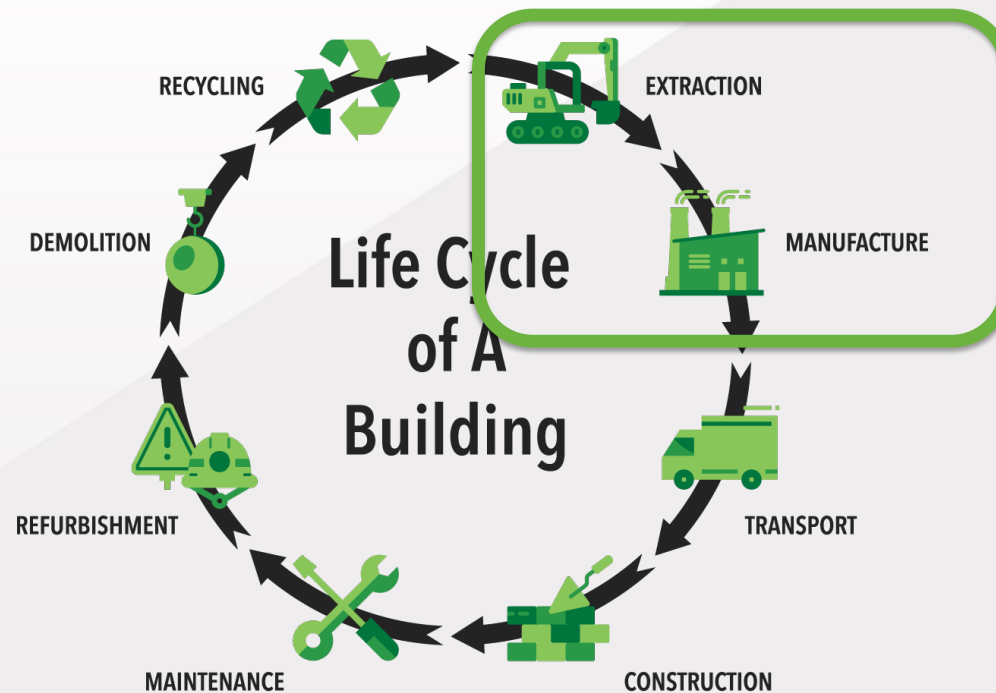
09/07/2021



11/13/2021



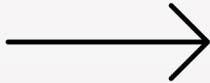
What is “Embodied”?



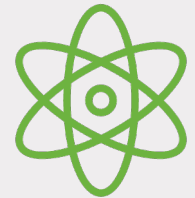
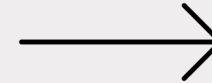
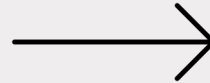
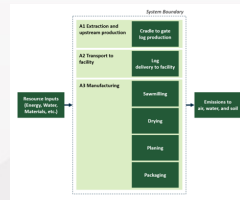
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Strategy



Inventory of Carbon
and Energy



Environmental
Product Declaration



Embodied Carbon in
Construction Calculator



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QUESTIONS

Outdoor
Concrete

×

22.5
 yd^3

×

320 $kgCO_2/yd^3$

≈

7000 $kgCO_2$

Material

Quantity

Carbon
Coefficient

Total Embodied
Carbon



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QUESTIONS

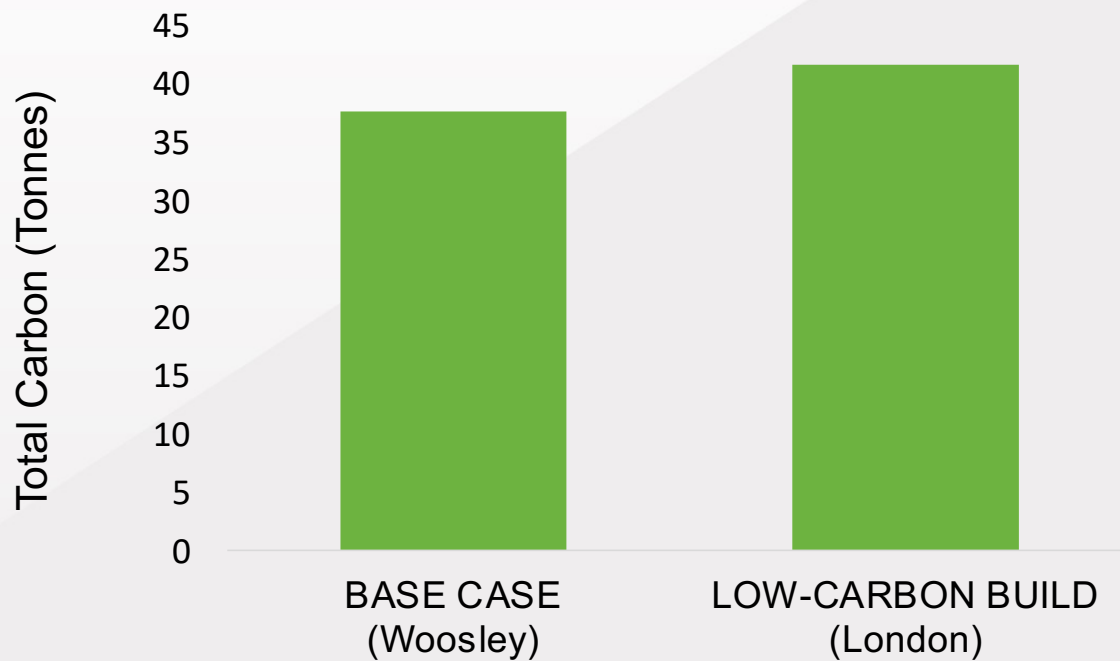
Material/House Portion	Quantity: (Units)	Embodied carbon per unit (Units)	Total Embodied Carbon (kgCO2)	Emitted Carbon:
Outdoor Concrete Foundation:	25 yd3	320 kgCO2/yd3	8000	41,599.49 kgCO2
Components Below:			-	
-exterior walls	16 m3	420 kgCO2/m3	6720	
-footing	4.5 m3	420 kgCO2/m3	1890	
-flooring	10 m3	420 kgCO2/m3	4200	
-rebar	0.04 m3	5369.4 kgCO2/m3	214.776	
-insulation	14 m3	66 kgCO2/m3	924	
Rough Carpentry	19.25 yd3	48 kgCO2/yd3	924	
Insulation: Components Below:			-	
-dowfoam	1855 ft2	2.13 kgCO2/ft2	3951	
-cellulose	463.75 ft2	0.106 kgCO2/ft2	49	
-cellulose	927.5 ft2	0.106 kgCO2/ft2	98	
Siding Components In Siding Work Sheet			1512	
Roofing	140 m2	4.8 kgCO2/m2	672	
HVAC	133 ft2	17.7 kgCO2/ft2	2354.1	
Finish Carpentry	750 kg	1.29 kgCO2/kg	967.5	
			0	
			0	
Misc Work: Components below			-	
Dow Foam	1120 ft2	0.515 kgCO2/ft2	576.8	
Egress window	20.5 lb	67 kgCO2/lb	1373.5	
cabinets	112 kg	0.7 kgCO2/kg	78.4	
Gutters	16 kg	3 kgCO2/kg	48	
House Wrap	20 kg	0.335 kgCO2/kg	6.7	
Pipe insulation	6 kg	1.5 kgCO2/kg	9	
Caulk	5.91 kg	1.2 kgCO2/kg	7.092	
Windows	13 units	85 kgCO2/window	1105	
Exterior doors	3 units	112 kgCO2/door	336	
Hardware	1	350	350	
Paint	155 ft2	1.6 kgCO2/ft2	248	
Appliances	370 kg	10.4 kgCO2/kg	3848	
Flooring	350 kg	1.5 kgCO2/kg	525	
Electrical	1500 m	0.25 kgCO2/m	375	
Plumbing	200 lb	1.18 kgCO2/lb	236	



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Embodied Carbon Comparison



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OVERVIEW

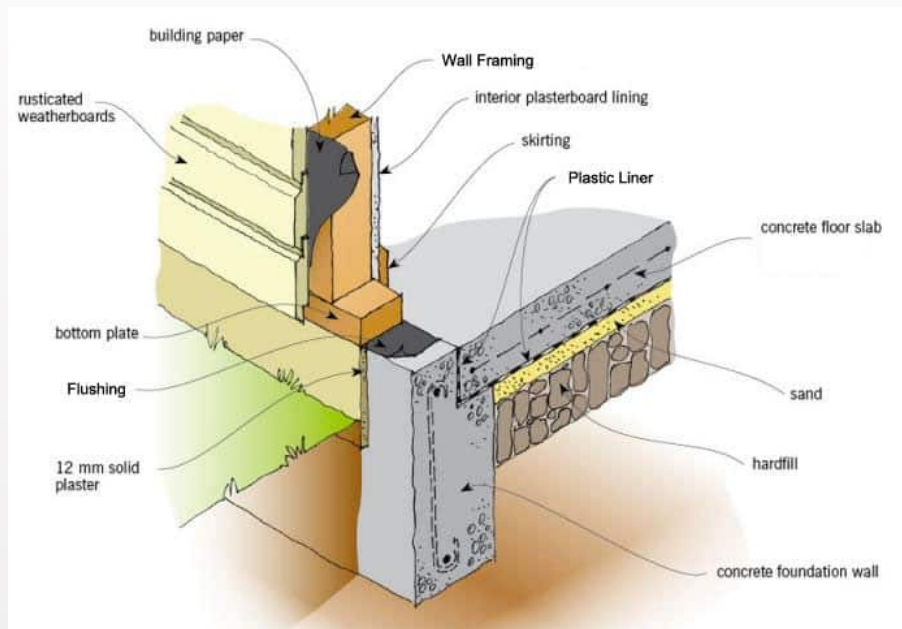
EMBODIED

ONSITE

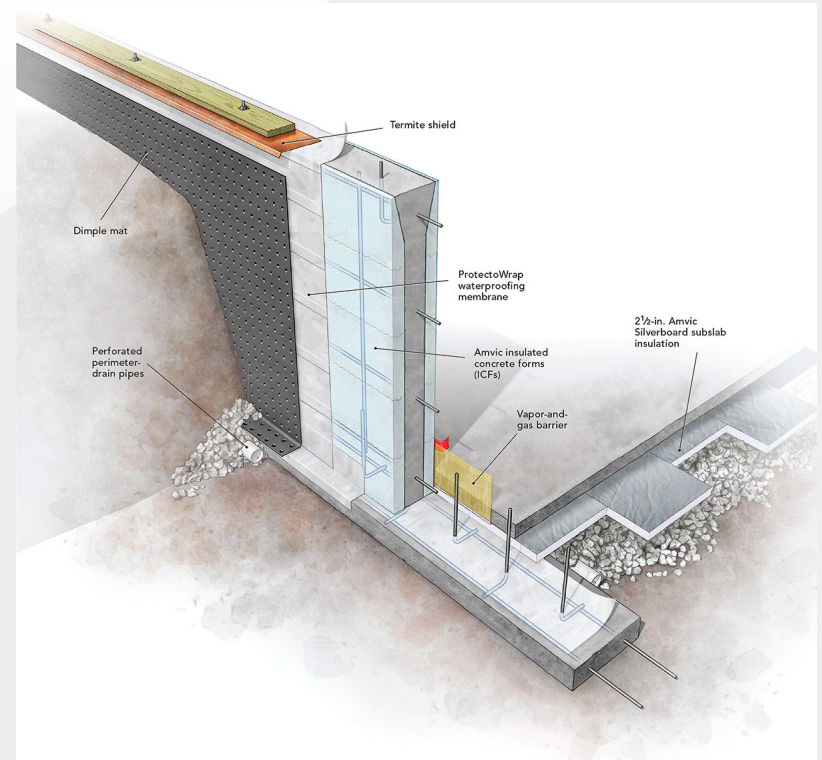
UTILITIES

DESIGN

QUESTIONS



Poured Concrete



Insulated Concrete
Forms (ICF)



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OVERVIEW

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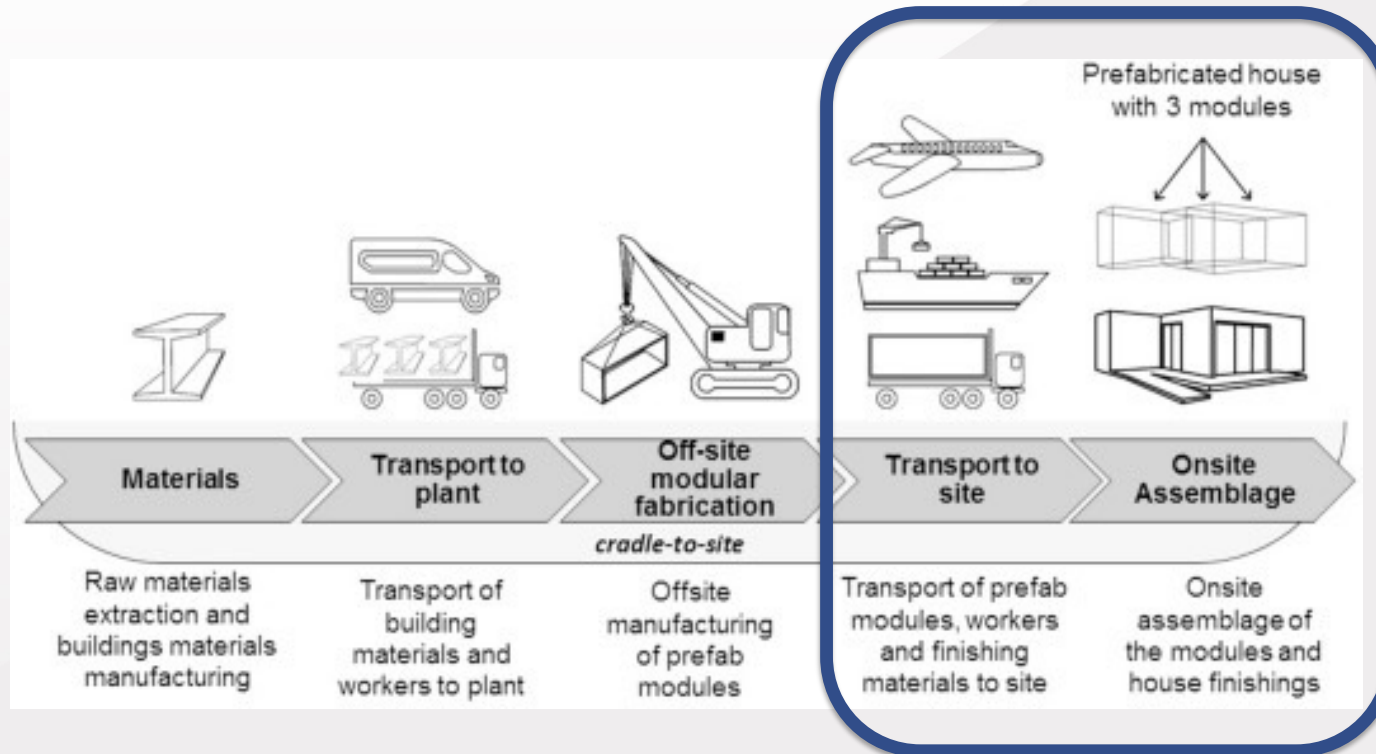
UTILITIES

DESIGN

QUESTIONS



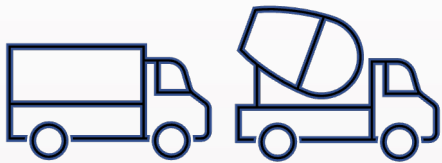
What is “Onsite”?



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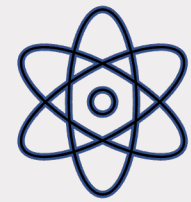
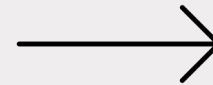
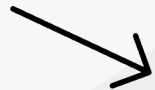
Strategy



Transportation



Construction Equipment



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QUESTIONS

$$8.0 \text{ hrs}_{(Air \text{ Compressor})} \times 3 \text{ gal}_{fuel}/\text{hr} \times 8.5 \text{ kgCO}_2/\text{gal}_{fuel} \approx 204 \text{ kgCO}_2$$

Activity Duration

Fuel Rate

Carbon
Coefficient

Total CO_2
Emissions

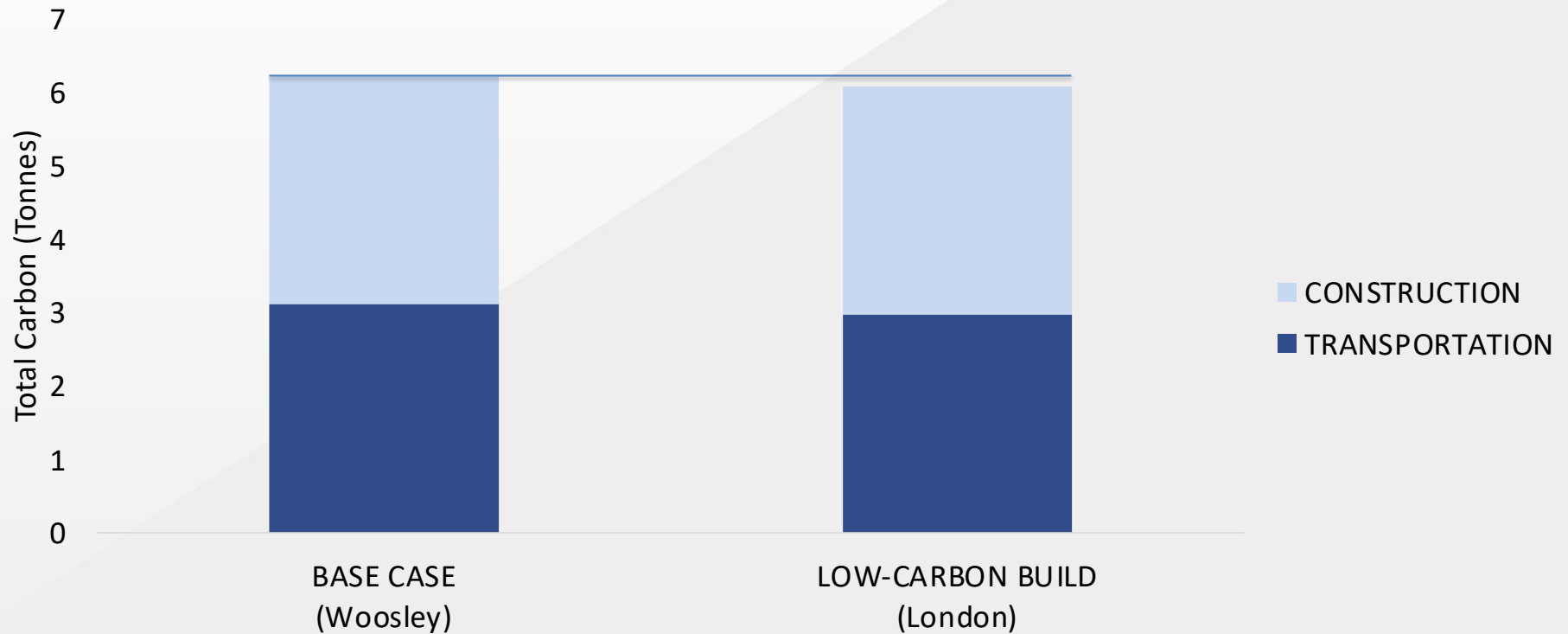


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Onsite Carbon Emissions Comparison

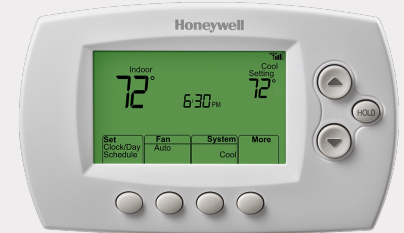


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What are “Utilities”?

- Utilities include:
 - Heating
 - Natural Gas
 - Electricity
 - Main Appliances
 - Lighting



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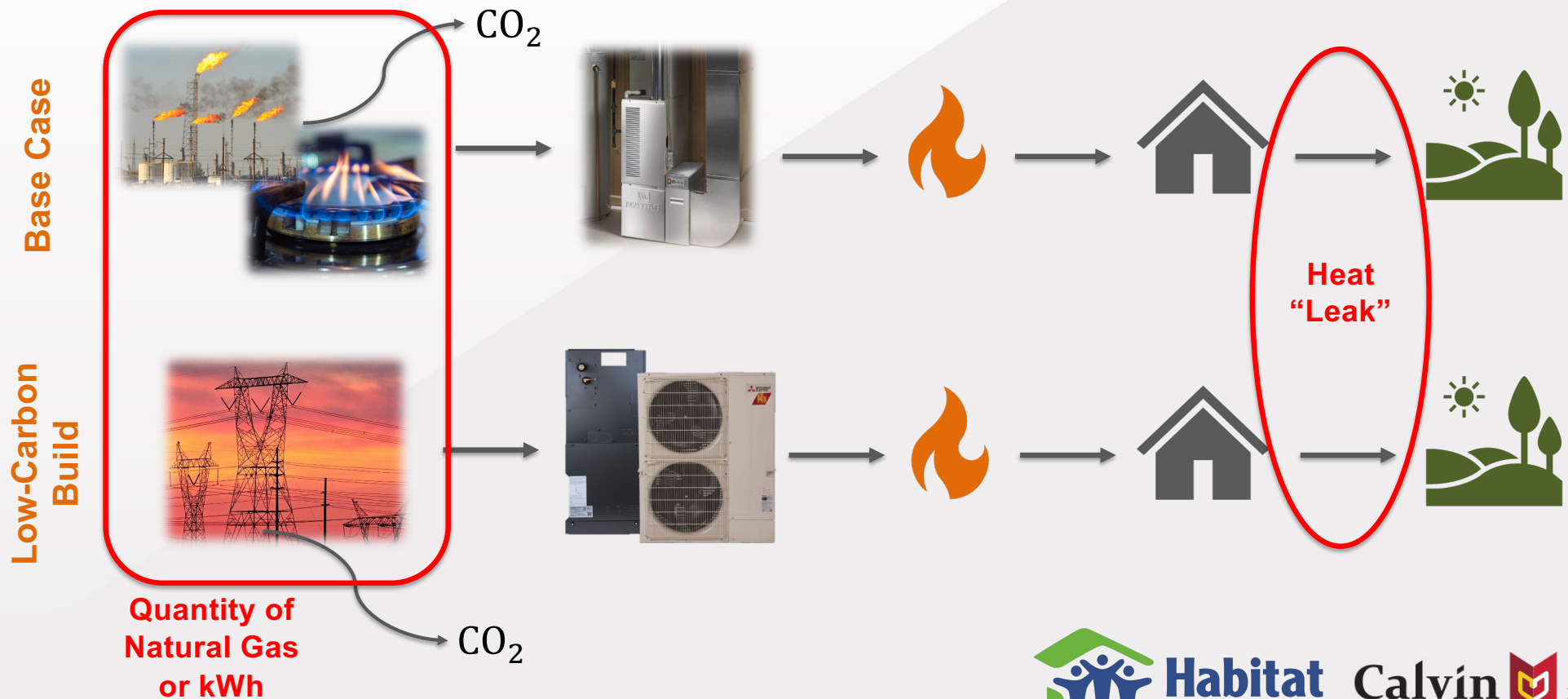
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Utilities – Fundamentally Different

- Embodied & Onsite: One-time
- Utilities
 - Reoccurring annually
 - 25-year period

Heating Analysis Procedure

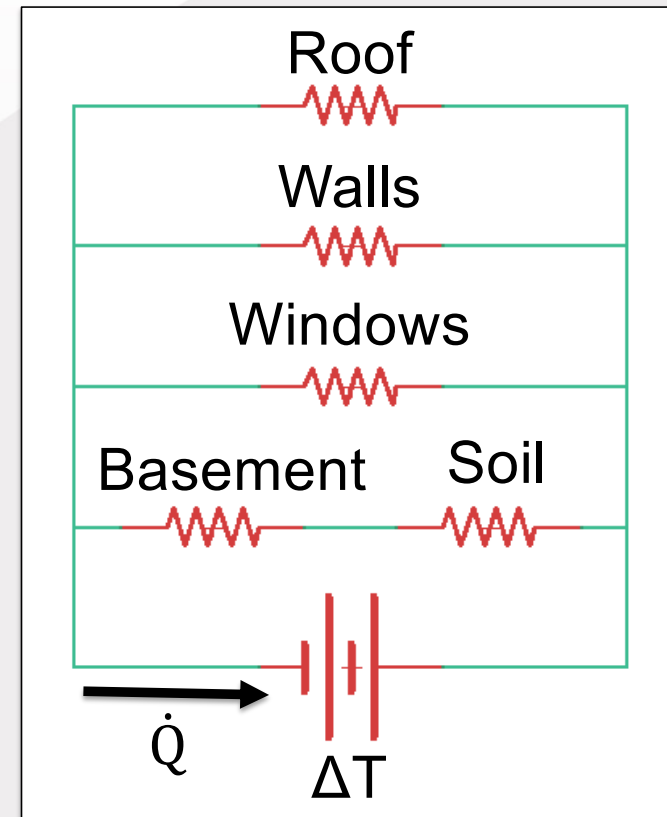
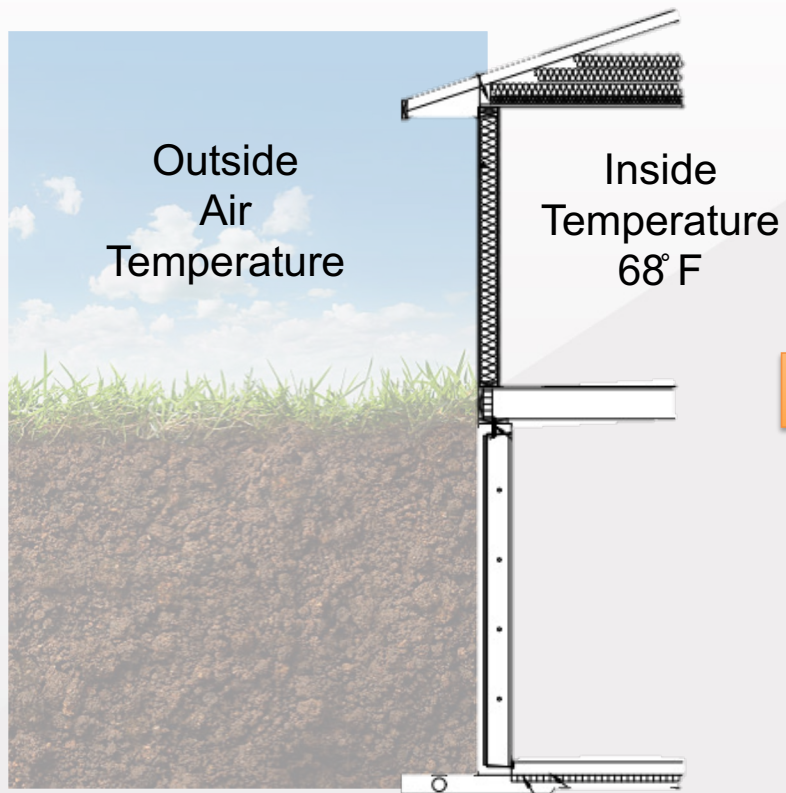


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Thermal Resistance Model – “Leak”



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Thermal Resistance Model

Ohm's Law

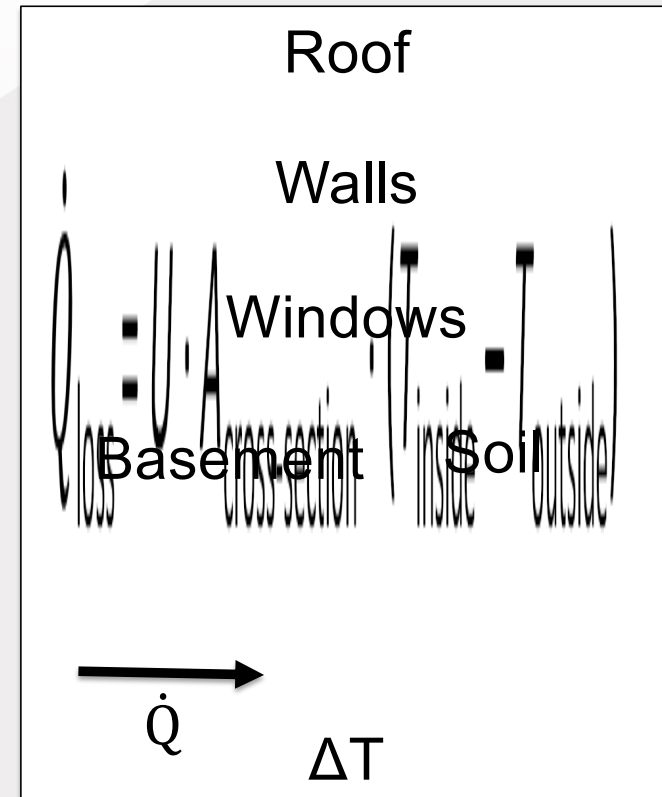
$$I = \Delta V / R$$

$$\Delta V \sim \Delta T \text{ (Heating Degree Day)}$$

$$R \sim 1 / (U \cdot A)$$

Thermal Equation:

$$\dot{Q}_{\text{loss}} = U \cdot A_{\text{cross-section}} \cdot (T_{\text{inside}} - T_{\text{outside}})$$

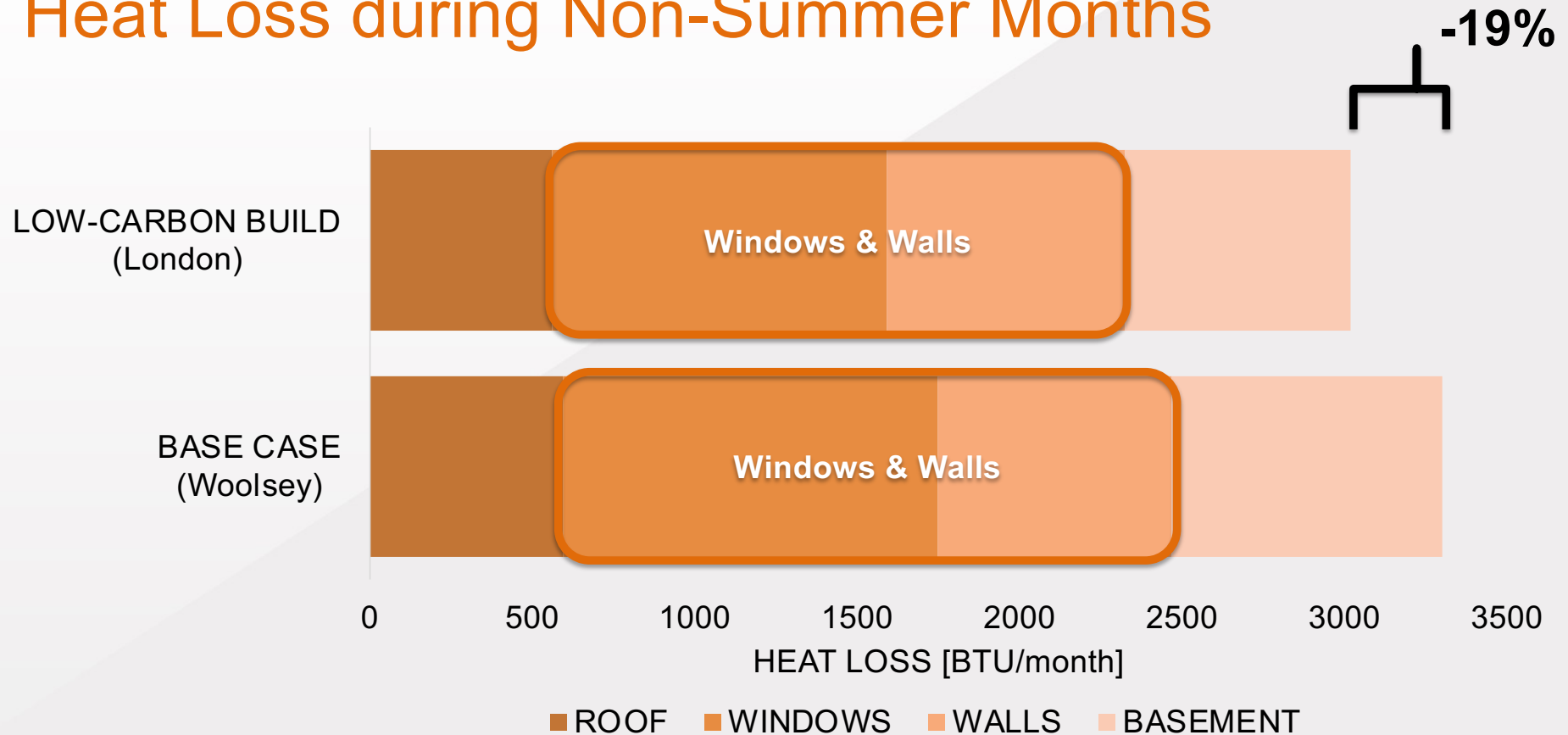


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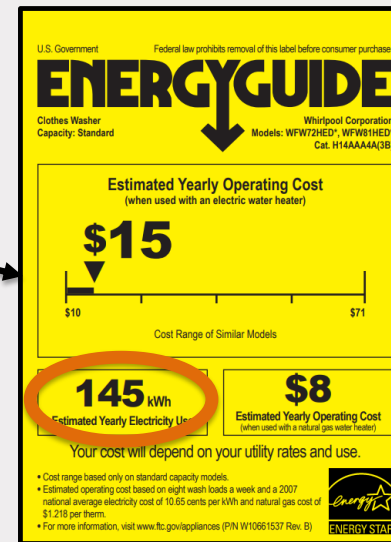
Heat Loss during Non-Summer Months



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Appliances Procedure



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Appliances Procedure



Range (Stovetop & Oven)



Water Heater

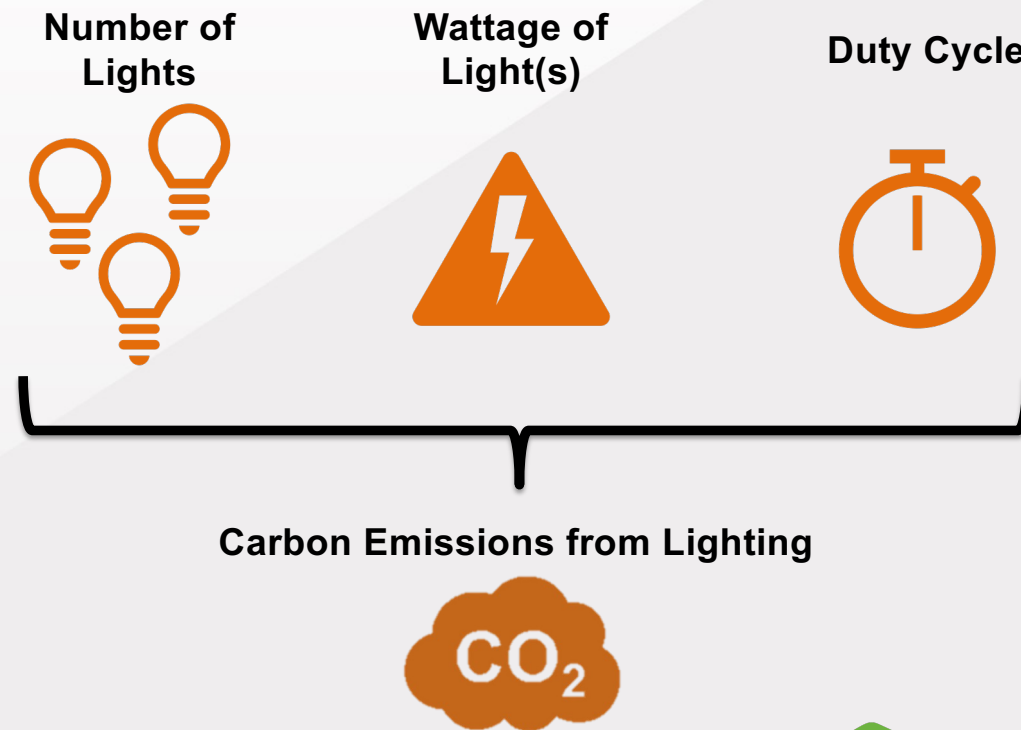


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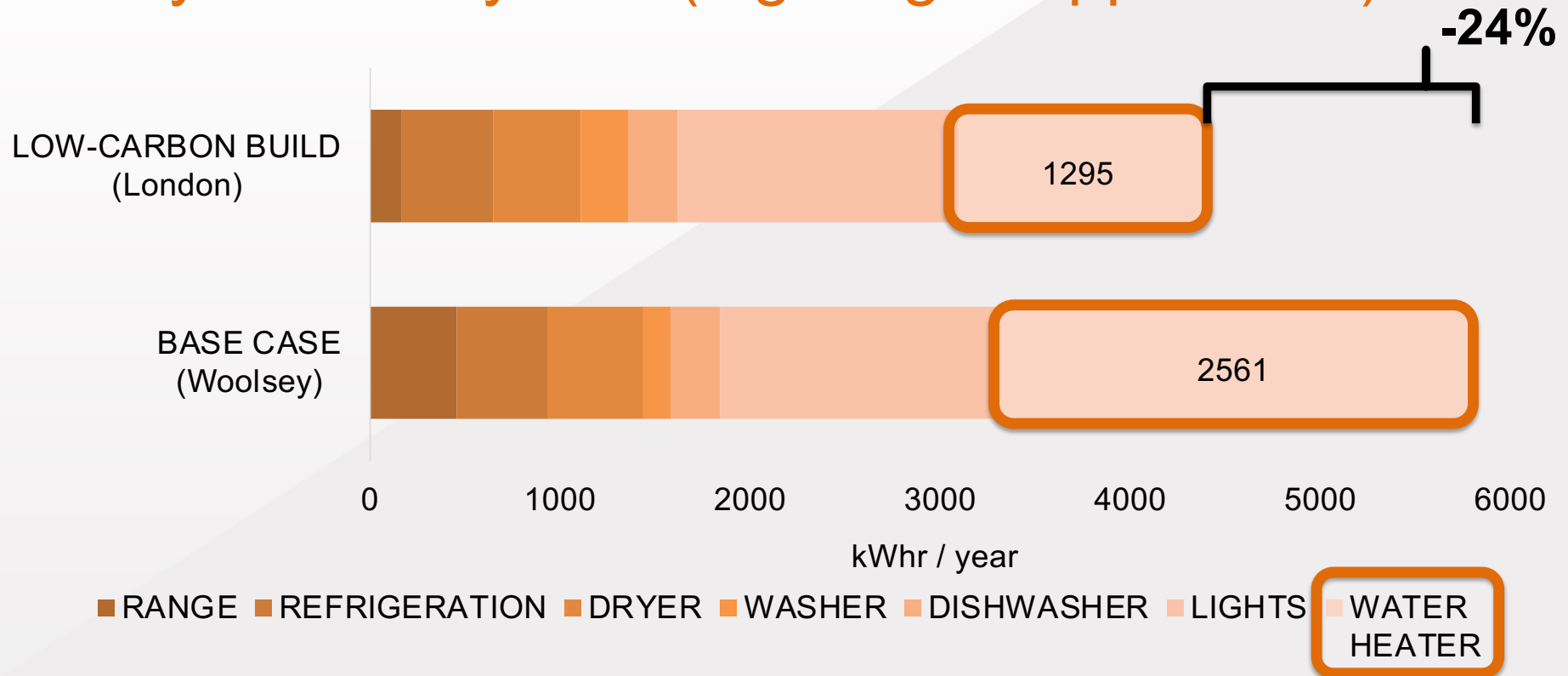
Lighting Procedure



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Yearly Electricity Use (Lighting & Appliances)

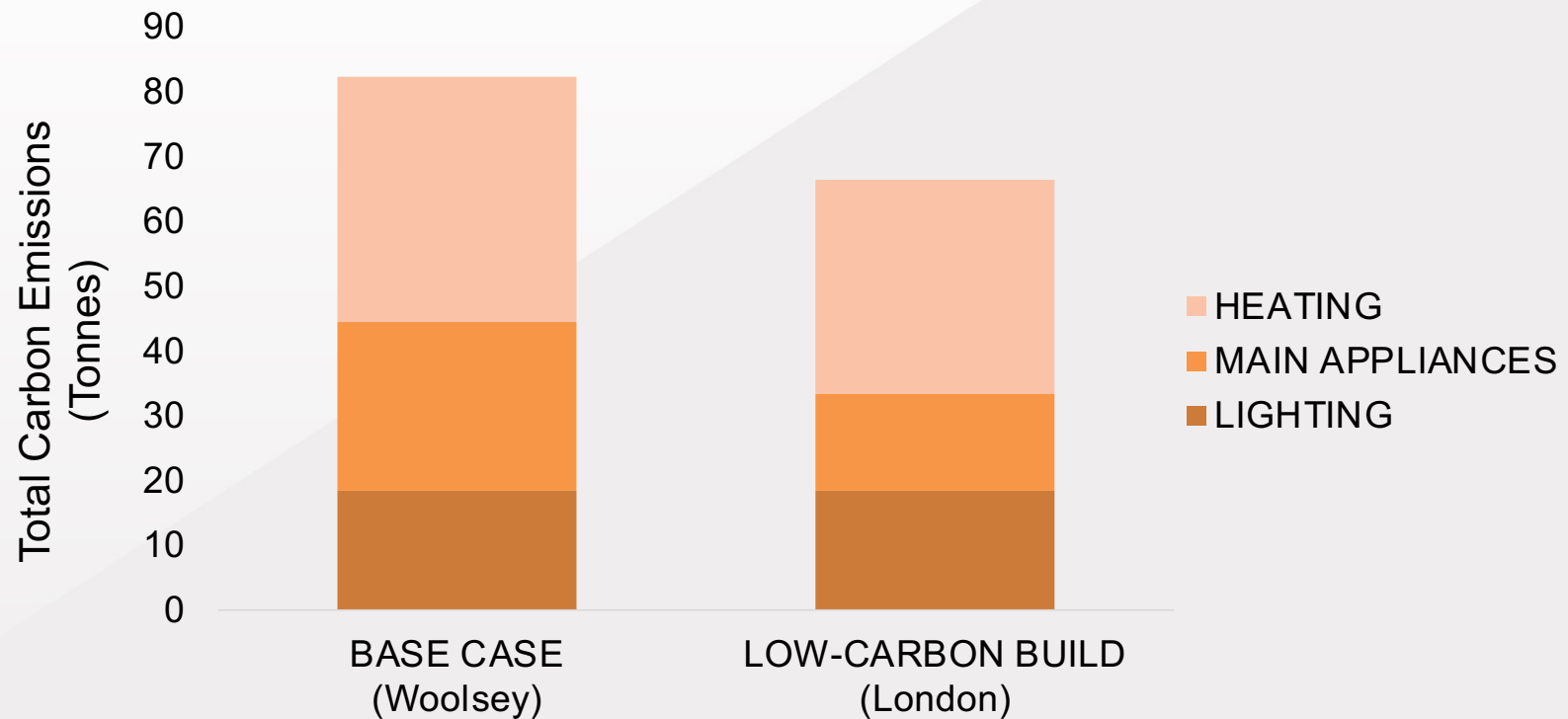


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Carbon Emissions from Utilities



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OVERVIEW

EMBODIED

ONSITE

UTILITIES

DESIGN

QUESTIONS



Analysis



Embodied



Onsite



Electricity



Heating

Utilities



Design

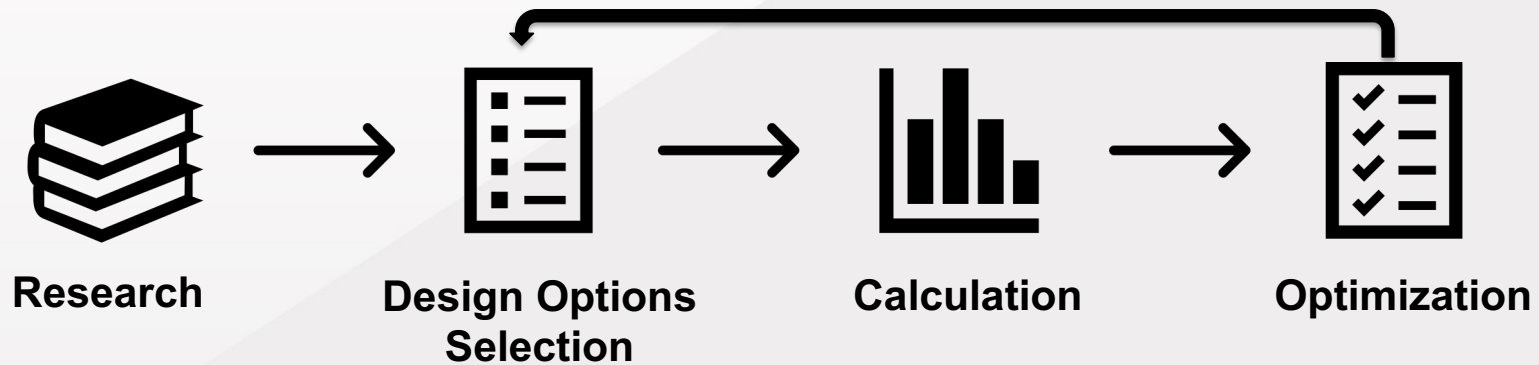


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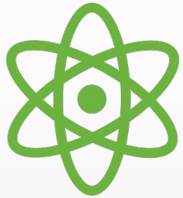
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Strategy



Design Options



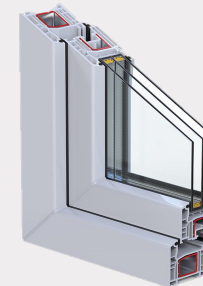
Prefabricated Concrete Basement



10 x 425-Watt Solar Panels
Solar Water Heater



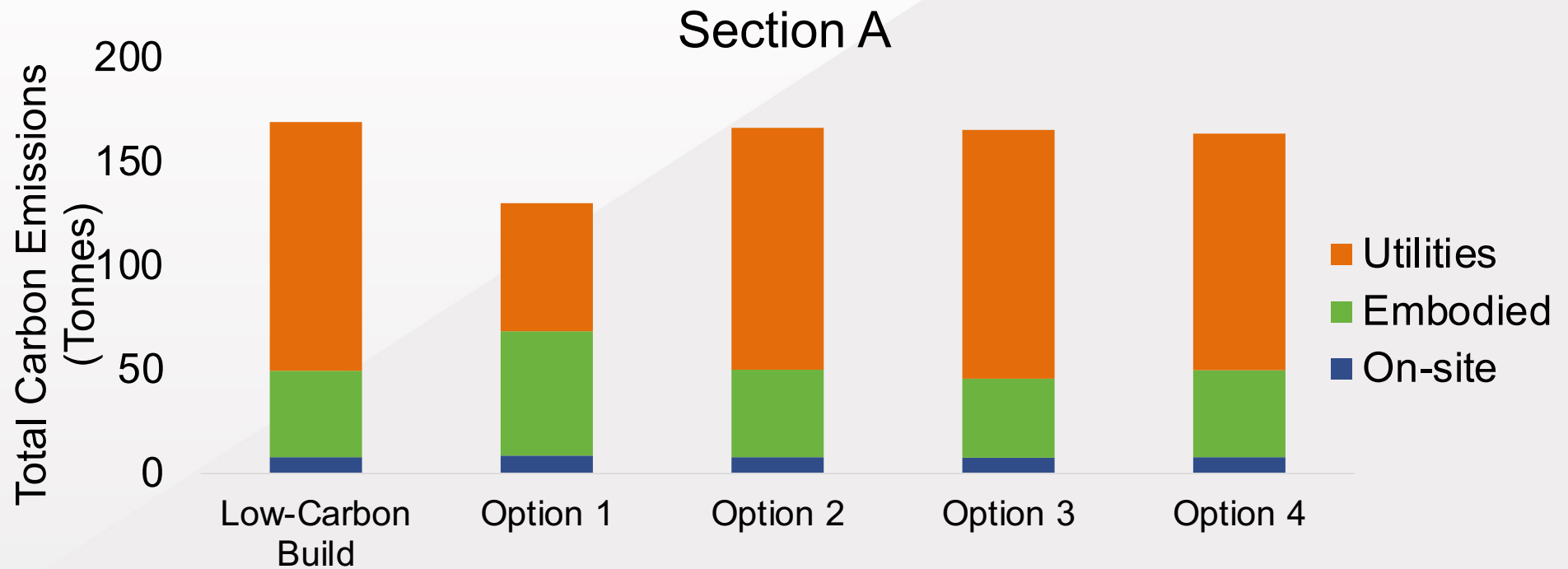
Triple Pane Windows
Insulation – type and thickness (6x)



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Low Carbon Design Options

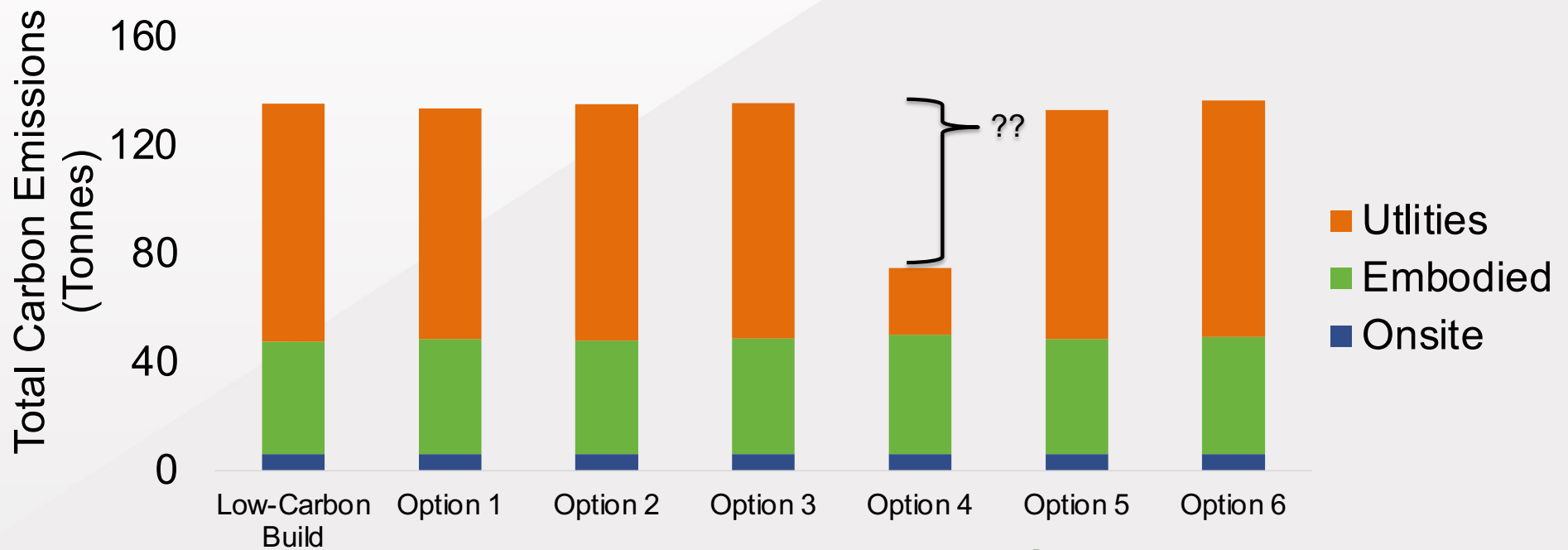


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Low Carbon Design Options

Section B

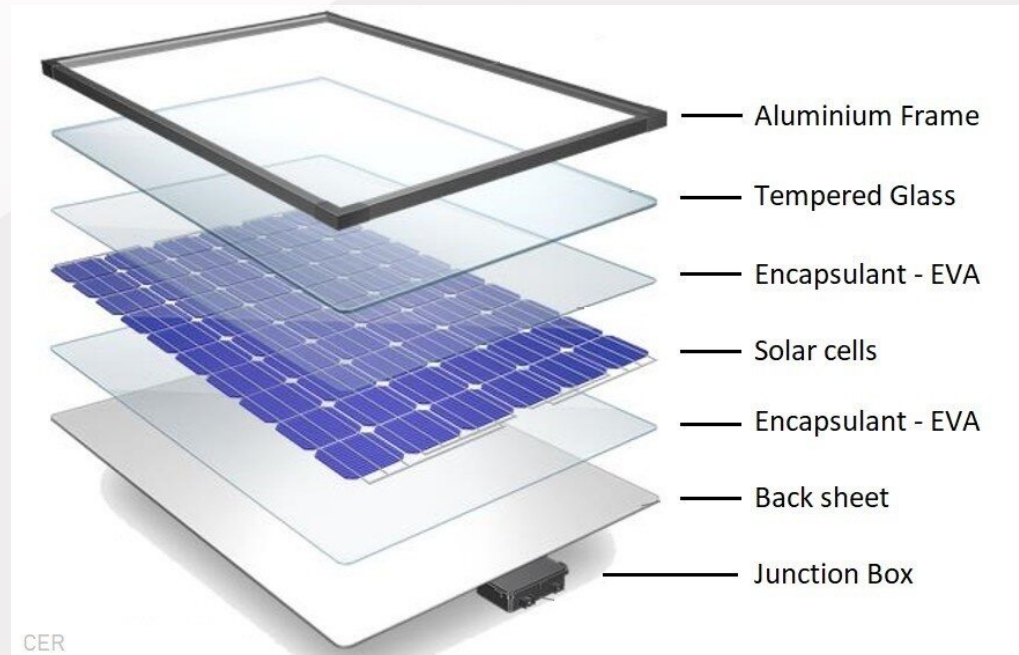


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Solar Power Tradeoffs

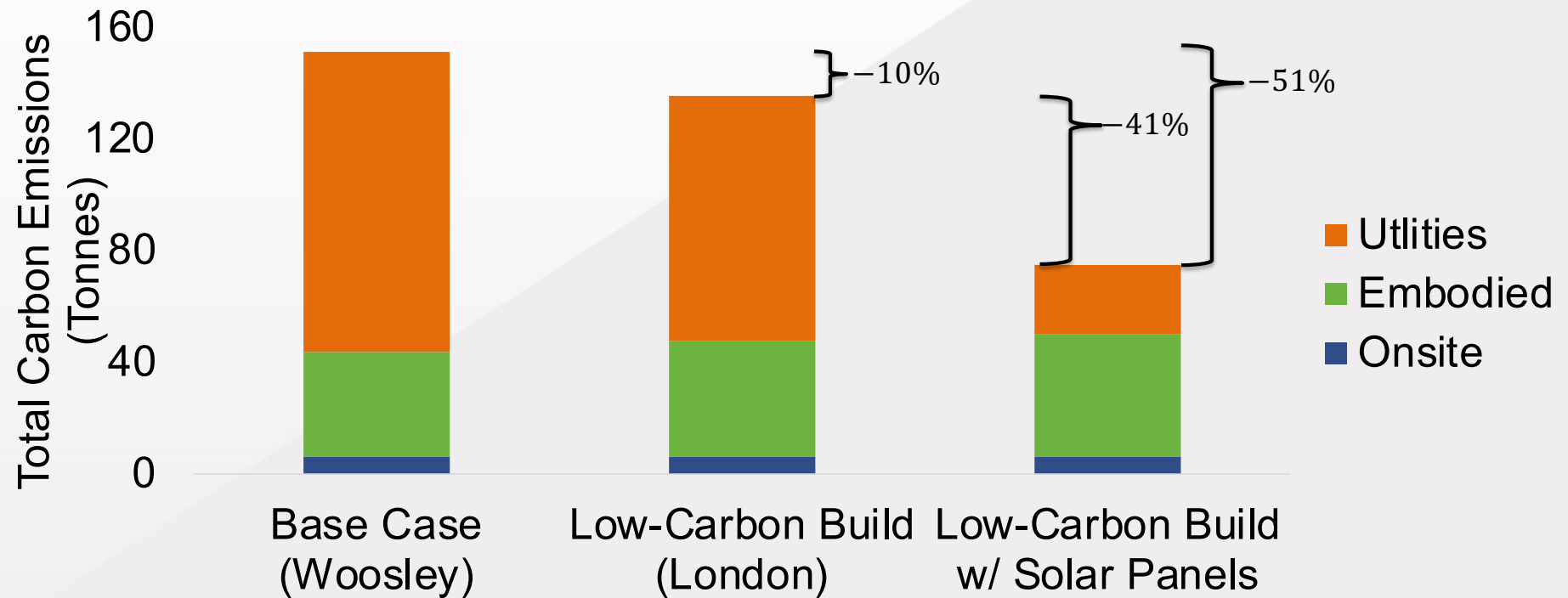
- Negatives
 - Carbon Intensive Steps
 - Need pure Silicon
- Positives
 - Renewable Energy
 - Lifetime benefits



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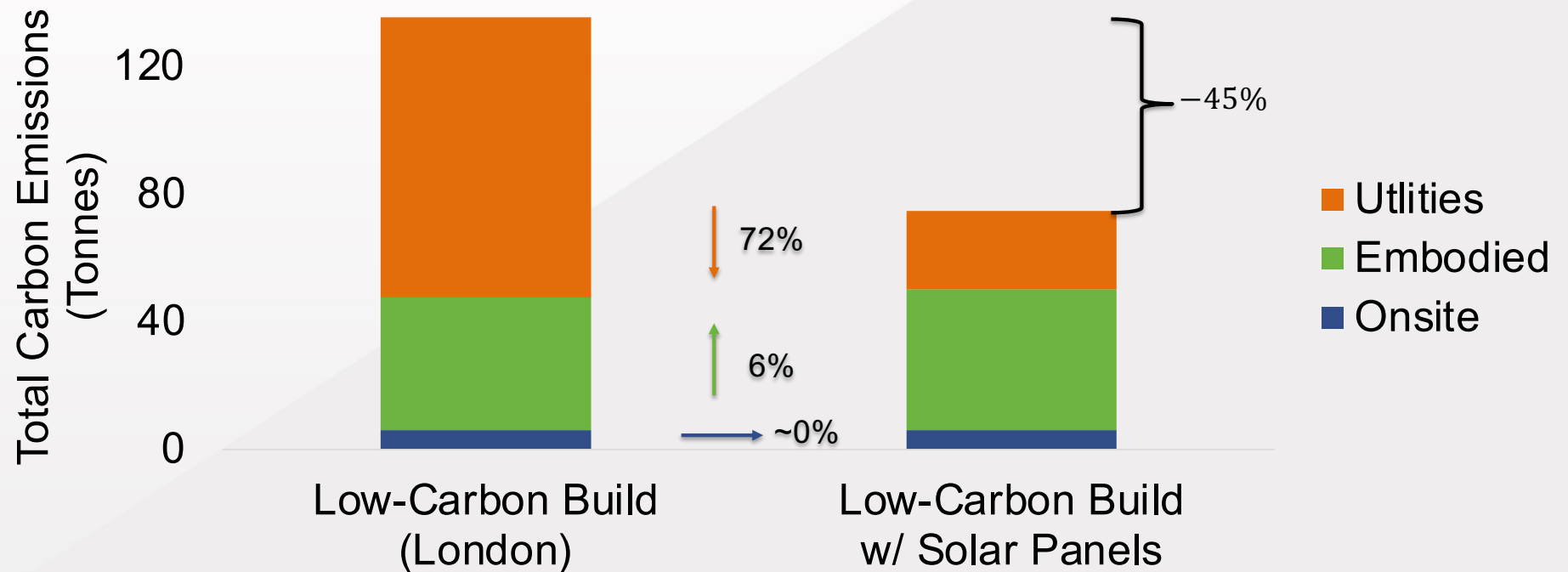
Studied Home Comparisons



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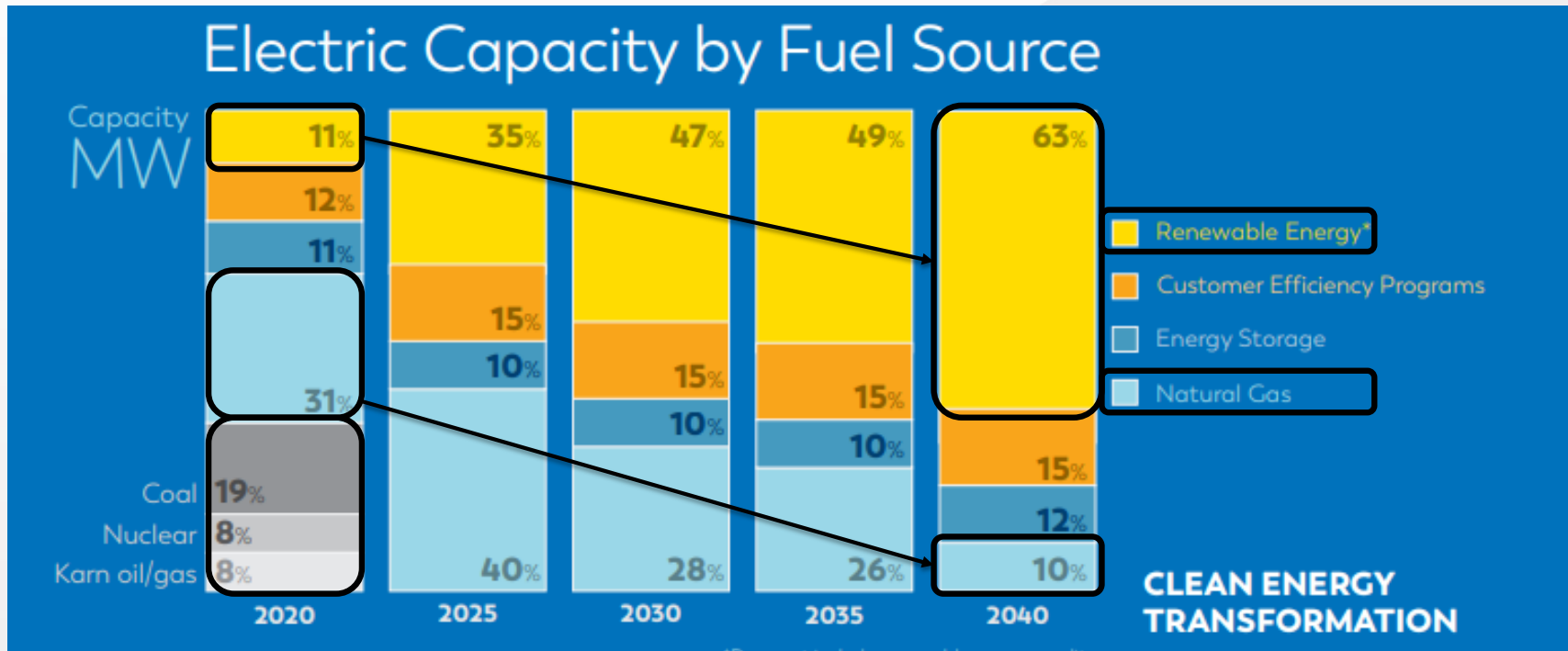
Studied Home Comparisons



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Consumers' Clean Energy Grid



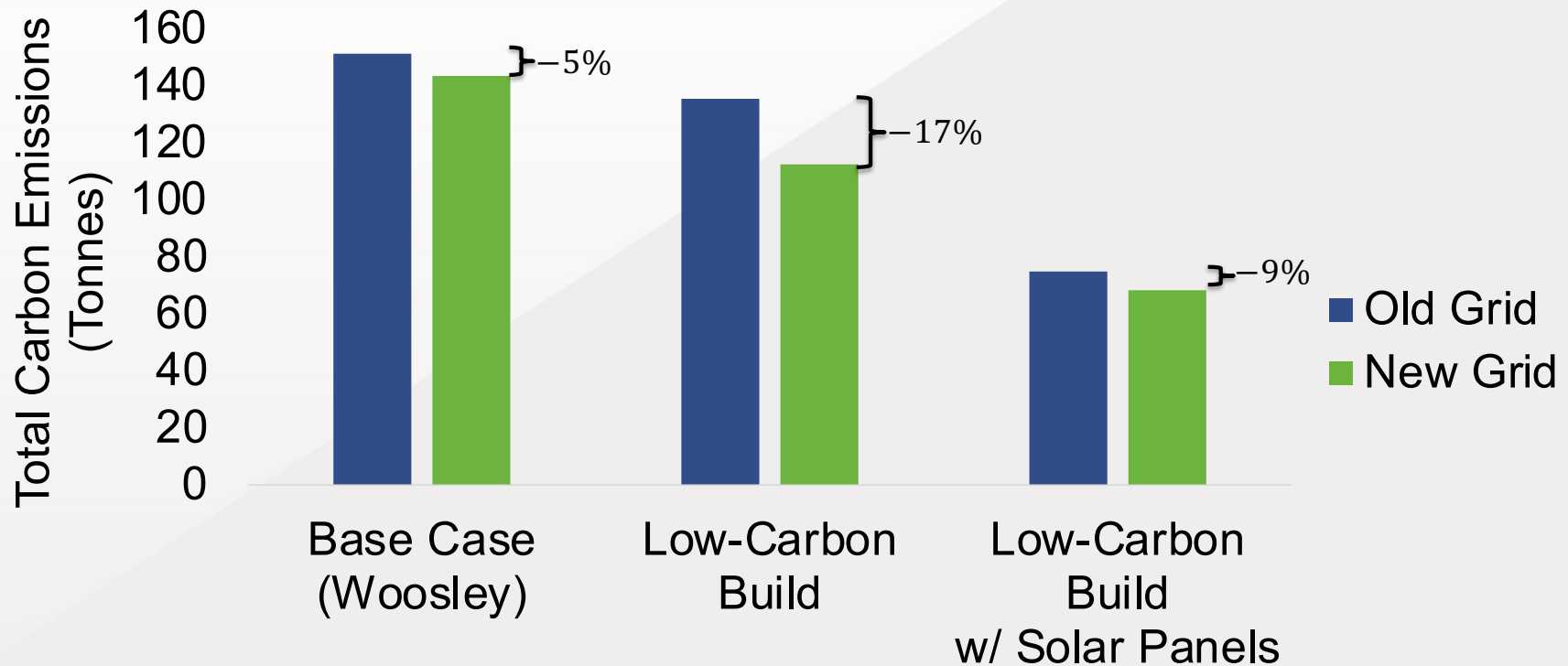
<https://www.consumersenergy.com/-/media/CE/Documents/company/IRP-2021.ashx>



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Clean Energy Grid Impacts



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Future Directions

Honorable Mentions

- Financial Analysis
- Additional design options
- Prefab Basement → -4%
- Solar Water Heater → -6%
- Triple Pane Windows → -3%
- Increased Insulation → -3%

Lessons Learned

- Large Teams are Unwieldy and Need Management
- Intergroup Communication is Necessary for Cohesive Results
- Boundaries are Important

Special Acknowledgements



John Marek



Mark Ogland-Hand

OVERVIEW

EMBODIED

ONSITE

UTILITIES

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Questions