12-1-2021

2021 Fall ENGR333 Seminar Presentation

Anika Huizinga

John Stehouwer

William Terpstra

Duncan Waanders

Low-Carbon Housing Project

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

Engineering Seminar SB010 | December 1st, 2021

Presented by Engineering 333

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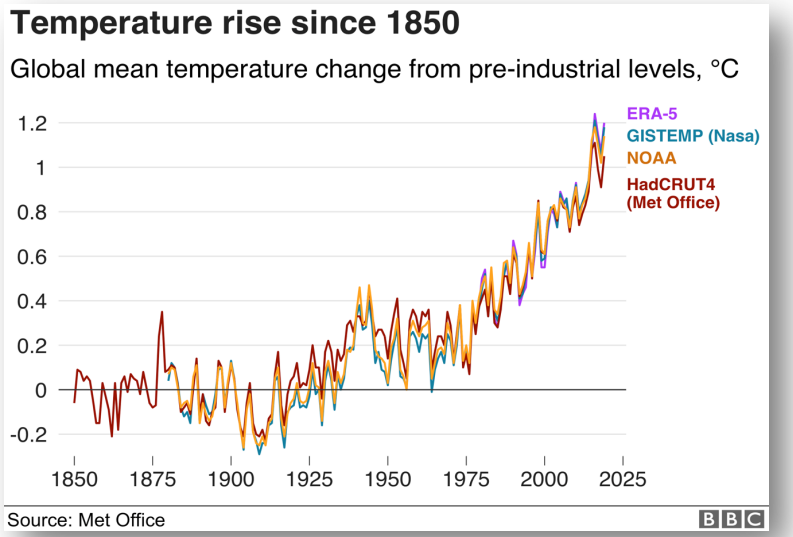
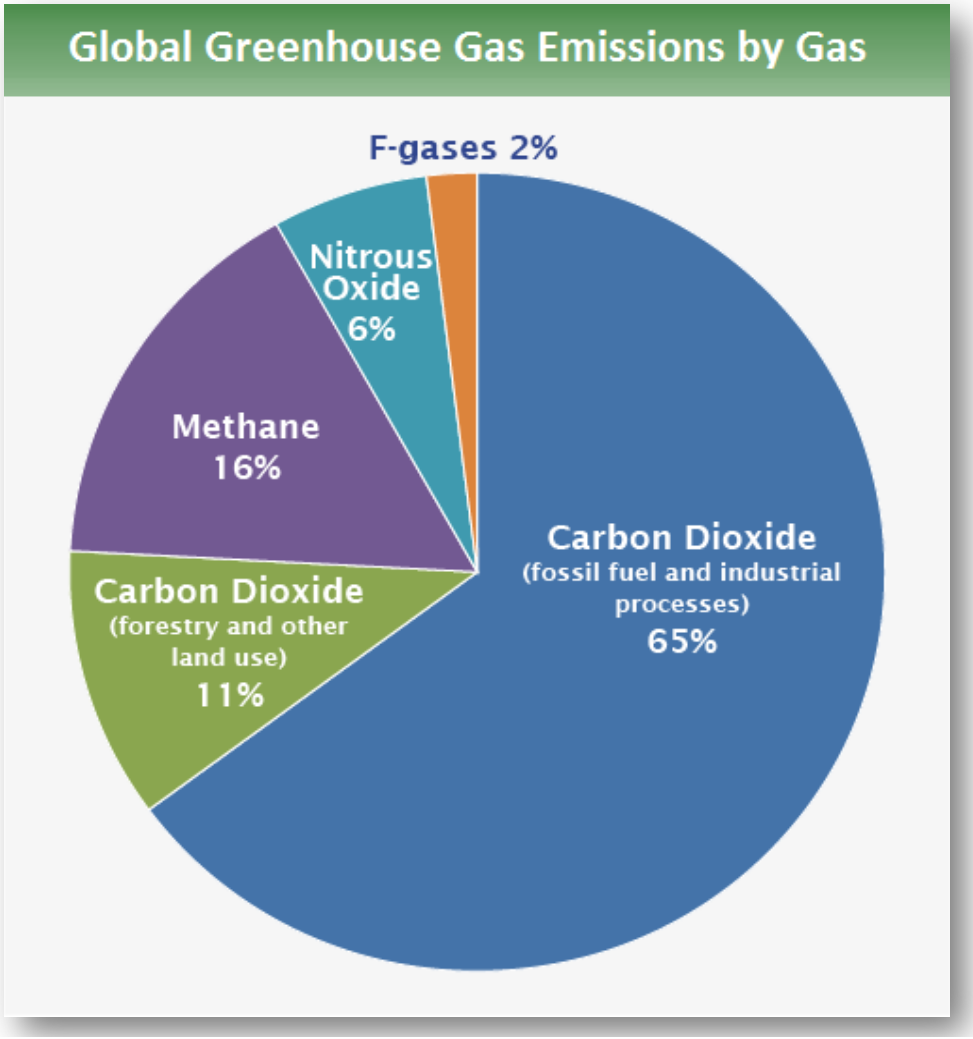
Outline

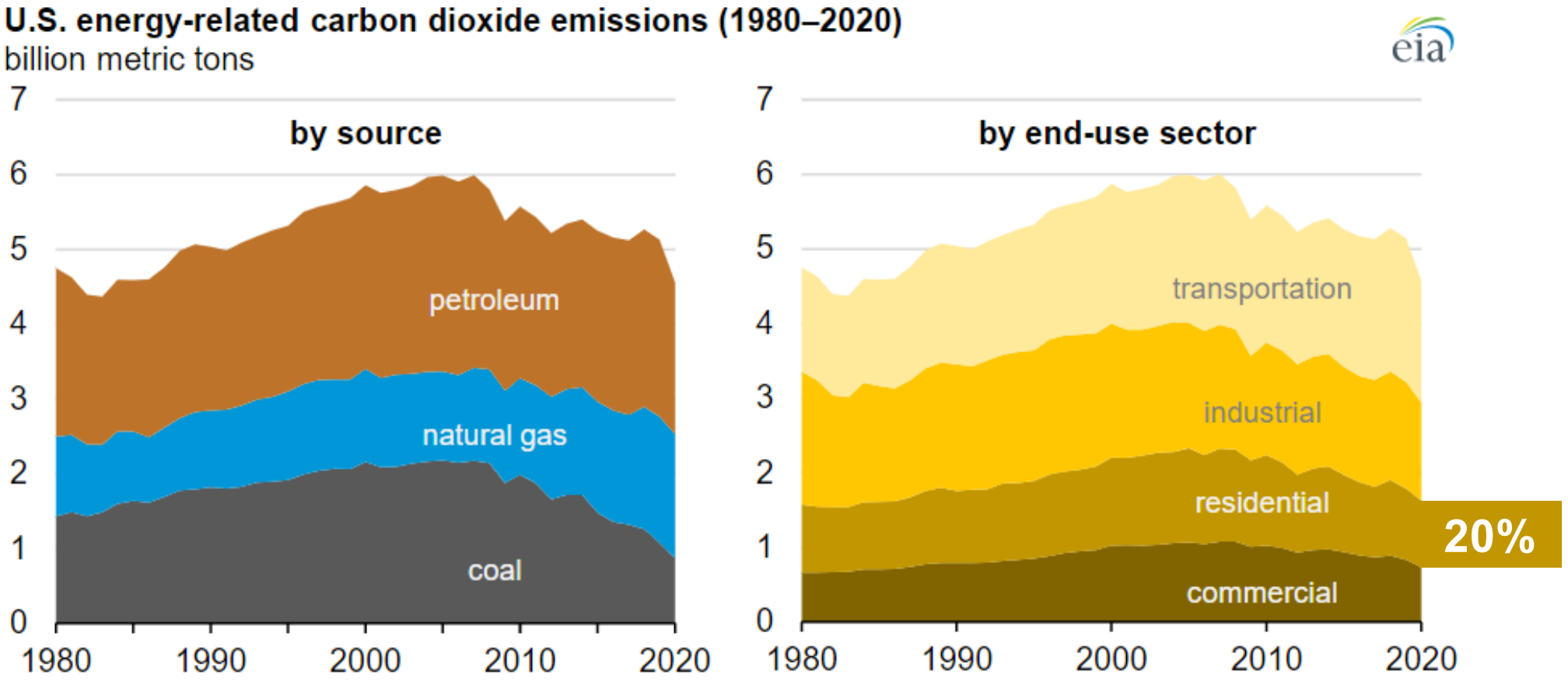
- Overview
- Teams
  - Embodied
  - Onsite
  - Utilities
  - Design
- Questions



UN CLIMATE CHANGE CONFERENCE UK 2021

IN PARTNERSHIP WITH ITALY




U.S. energy-related carbon dioxide emissions (1980–2020)
billion metric tons
eia
by source
petroleum
natural gas
coal
by end-use sector
transportation
industrial
residential
commercial
20%
0
1
2
3
4
5
6
7
1980
1990
2000
2010
2020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for Humanity®
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%?

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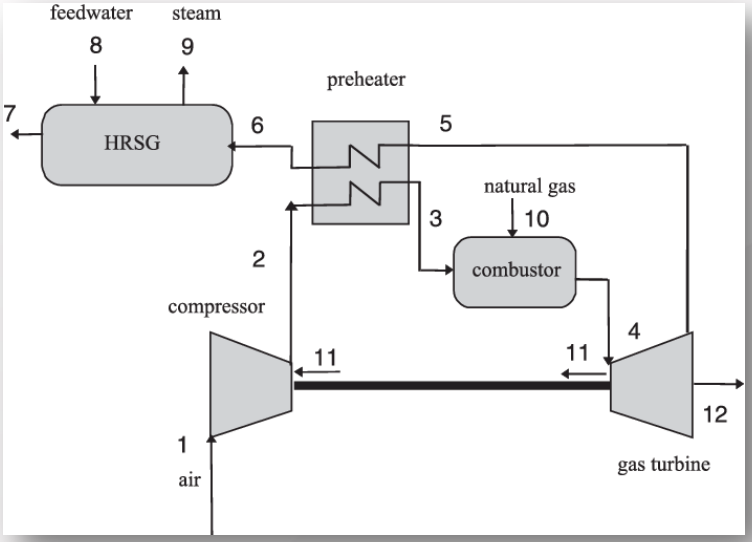
Connections to Thermal Systems Design



- Heat Transfer
- Energy Usage
- Material Properties

- Specification Research
- Unit Continuity

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Sections

Section A

Case Study: 536 Stolpe St SW

Section B

Case Study: 930 Woolsey Dr SW

Both Sections:

Low-Carbon Build: 726 London St SW

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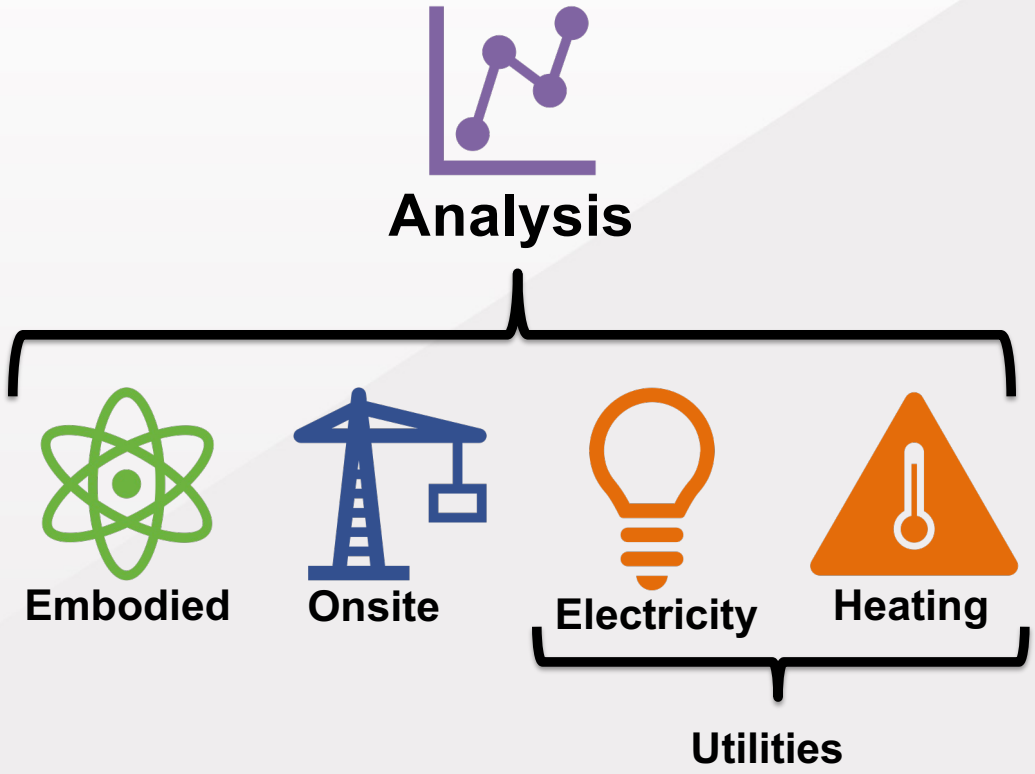
Section Organization



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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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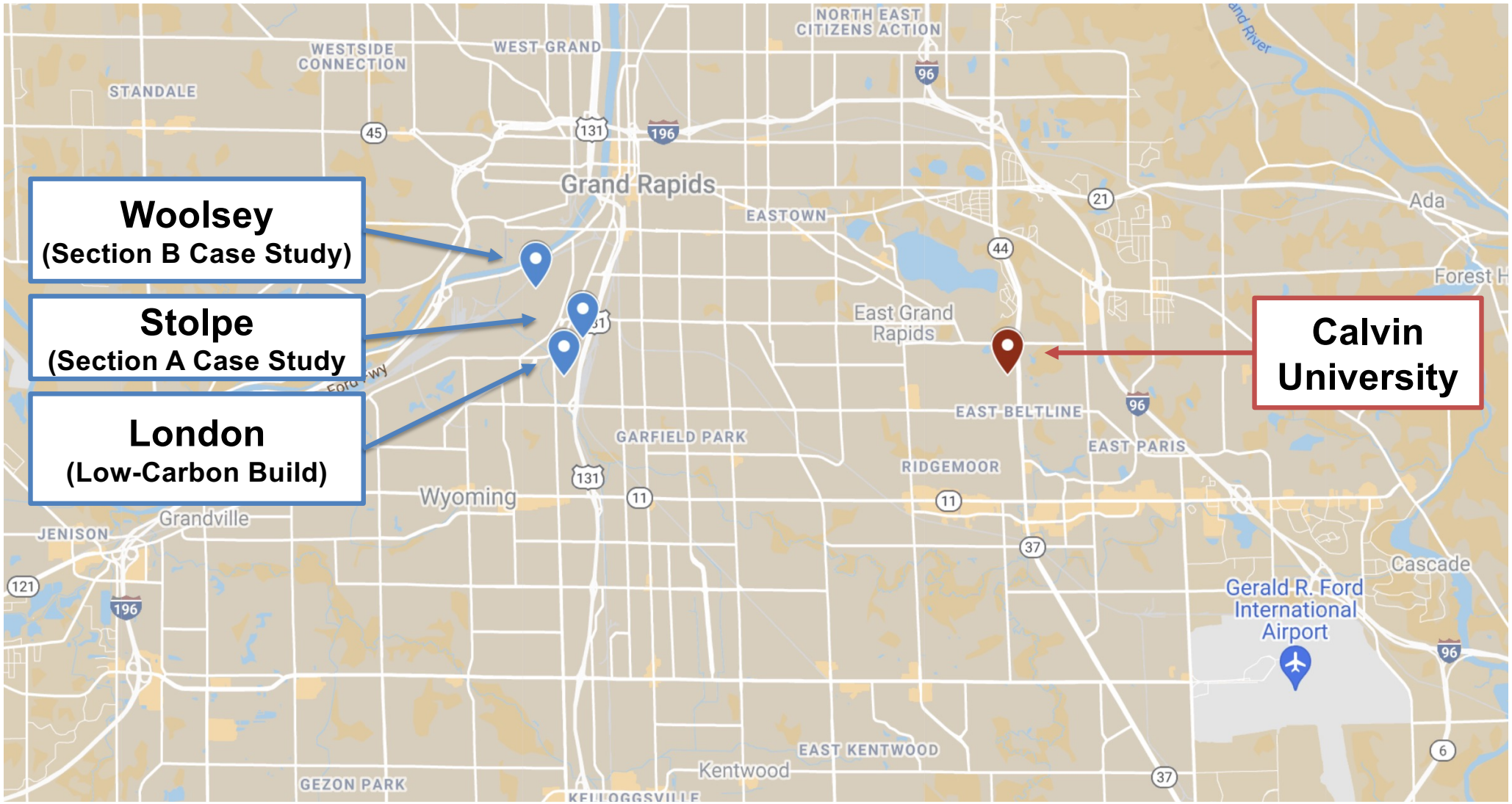
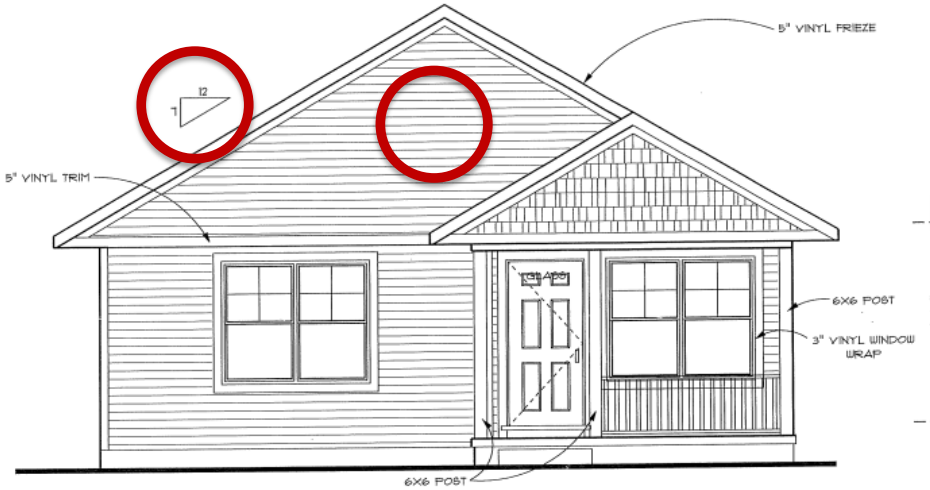

Woolsey
(Section B Case Study)
Stolpe
(Section A Case Study
London
(Low-Carbon Build)
Calvin University
NORTH EAST CITIZENS ACTION
WESTSIDE CONNECTION
WEST GRAND
STANDALE
Grand Rapids
EASTOWN
East Grand Rapids
Ada
EAST BELTLINE
GARFIELD PARK
EAST PARIS
RIDGEMOOR
Wyoming
Grandville
JENISON
Cascade
Gerald R. Ford International Airport
EAST KENTWOOD
Kentwood
GEZON PARK

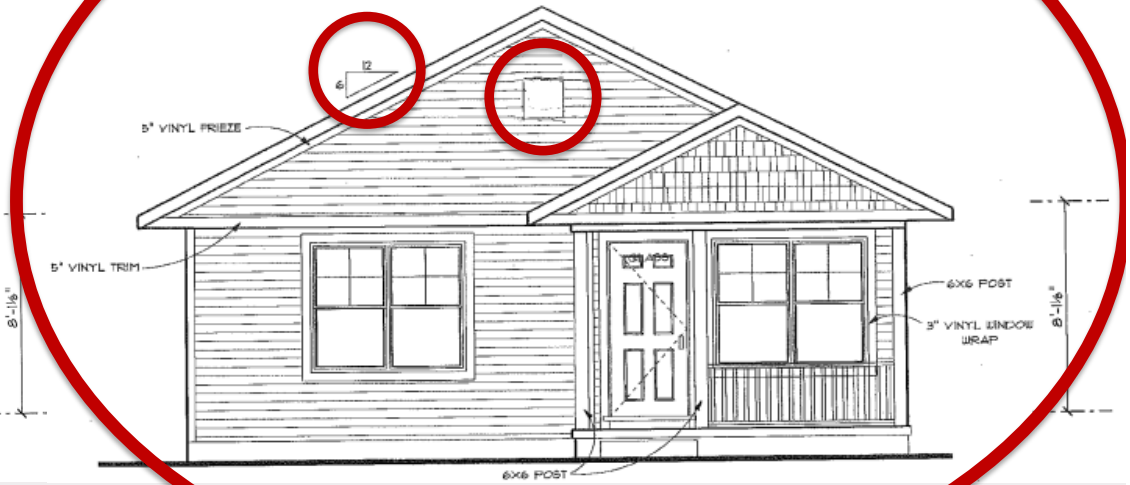
Team Differences

Section A
536 Stolpe Ave



~2019

Section B
930 Woolsey SW



~2015

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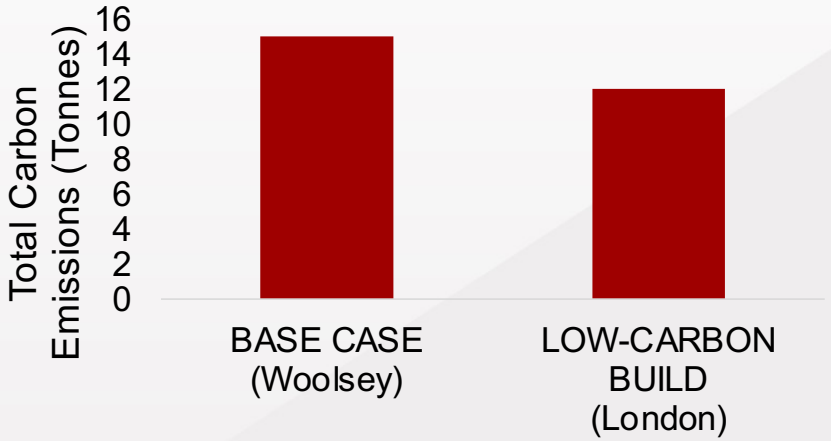
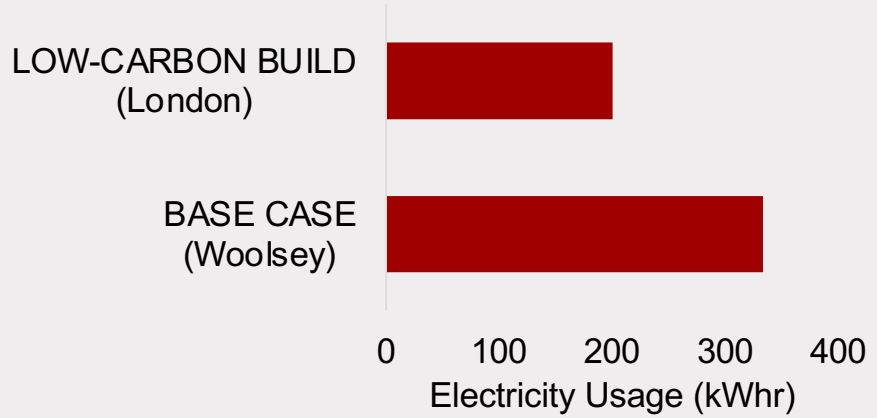
Note on Charts and Units

Vertical Bar Charts: Carbon Emissions



Horizontal Bar Charts: Usage Rates



Carbon Emission listed as Metric Tonnes

(1 Tonne = 1000 kg ≠ 2000 lbs)

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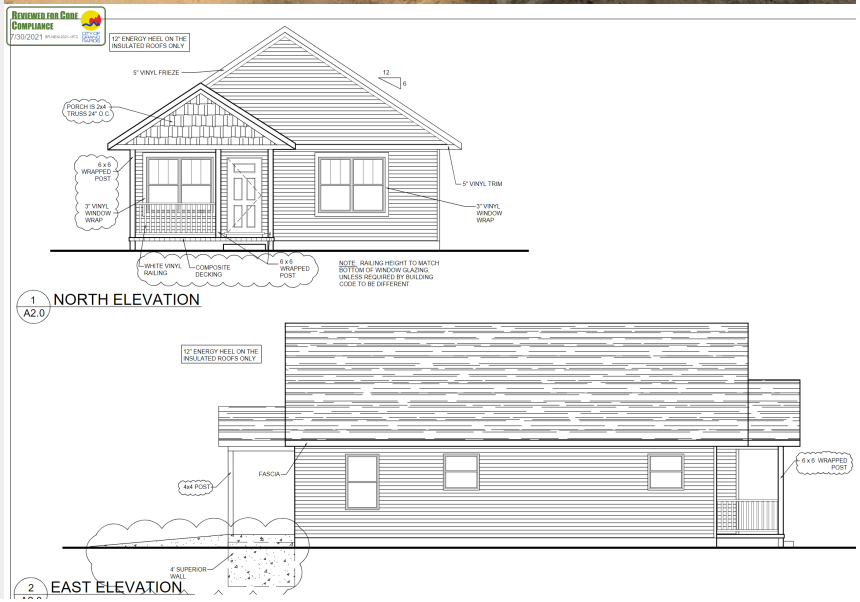
London:
Low-Carbon Build House

- **Insulated Concrete Forms Foundation**

- **All Electric**
  - Heat pump
  - Water Heater
  - Other Appliances

} Move Heat (Rather than Generate Heat)



London Progress

09/07/2021

11/13/2021

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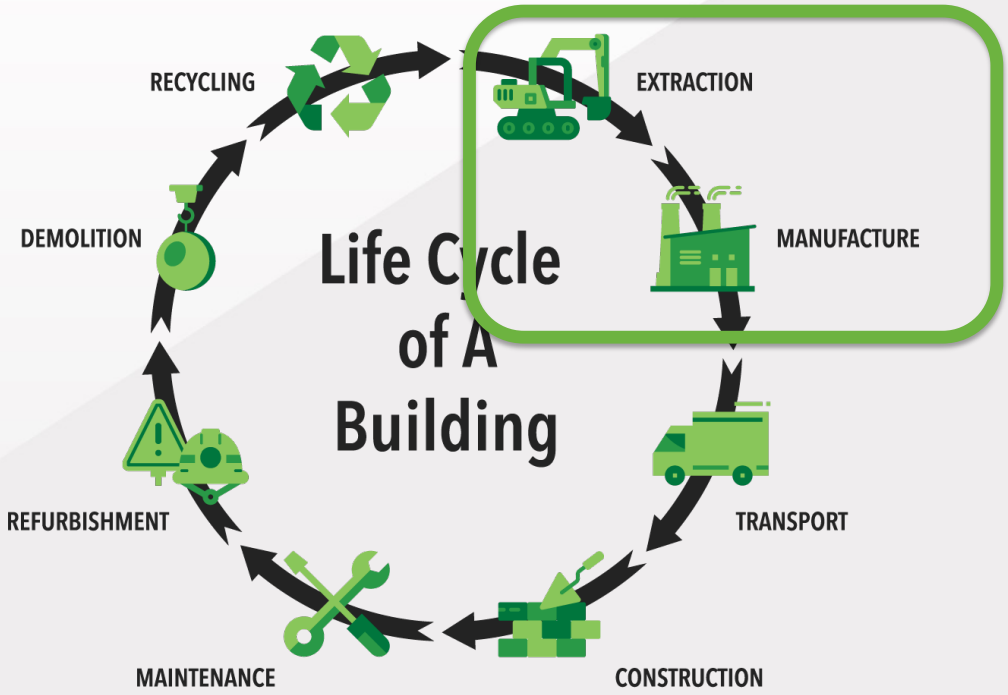
What is “Embodied”?



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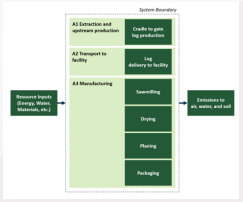
Strategy

Inventory of Carbon and Energy



Environmental Product Declaration

Embodied Carbon in Construction Calculator

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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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Material/House Portio	Quantity:	(Units)	Embodied carbon per un	(Units)	Total Embodied Carbon (kgCO2)	Emitted Carbon:	
Outdoor Concrete	25	yd3	320	kgCO2/yd3	8000	41,599.49	kgCO2
Foundation:			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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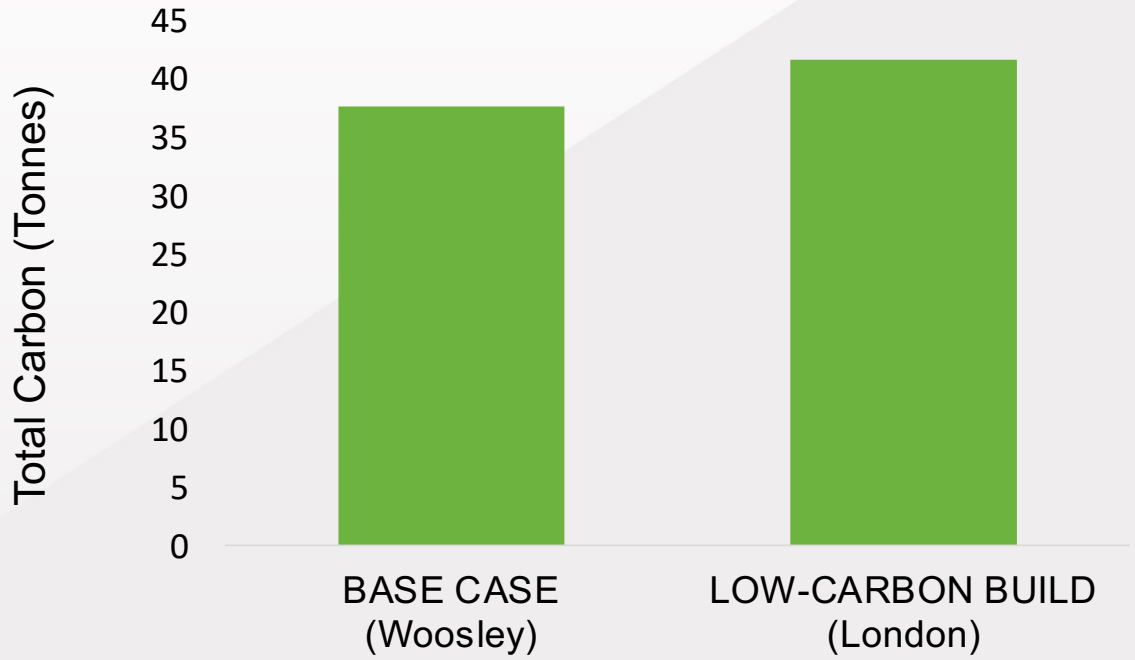
Embodied Carbon Comparison



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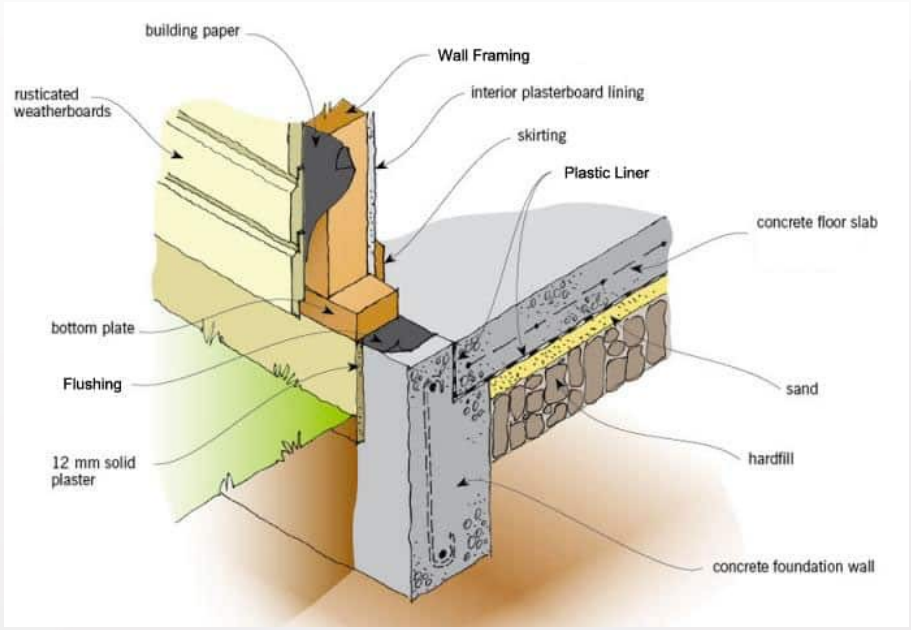
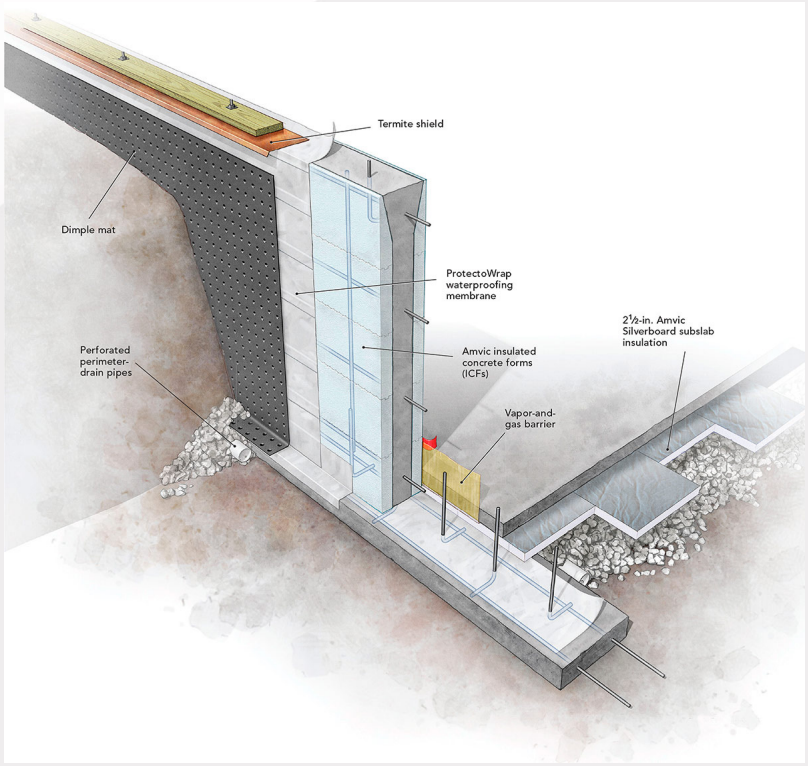


Poured Concrete



Insulated Concrete Forms (ICF)

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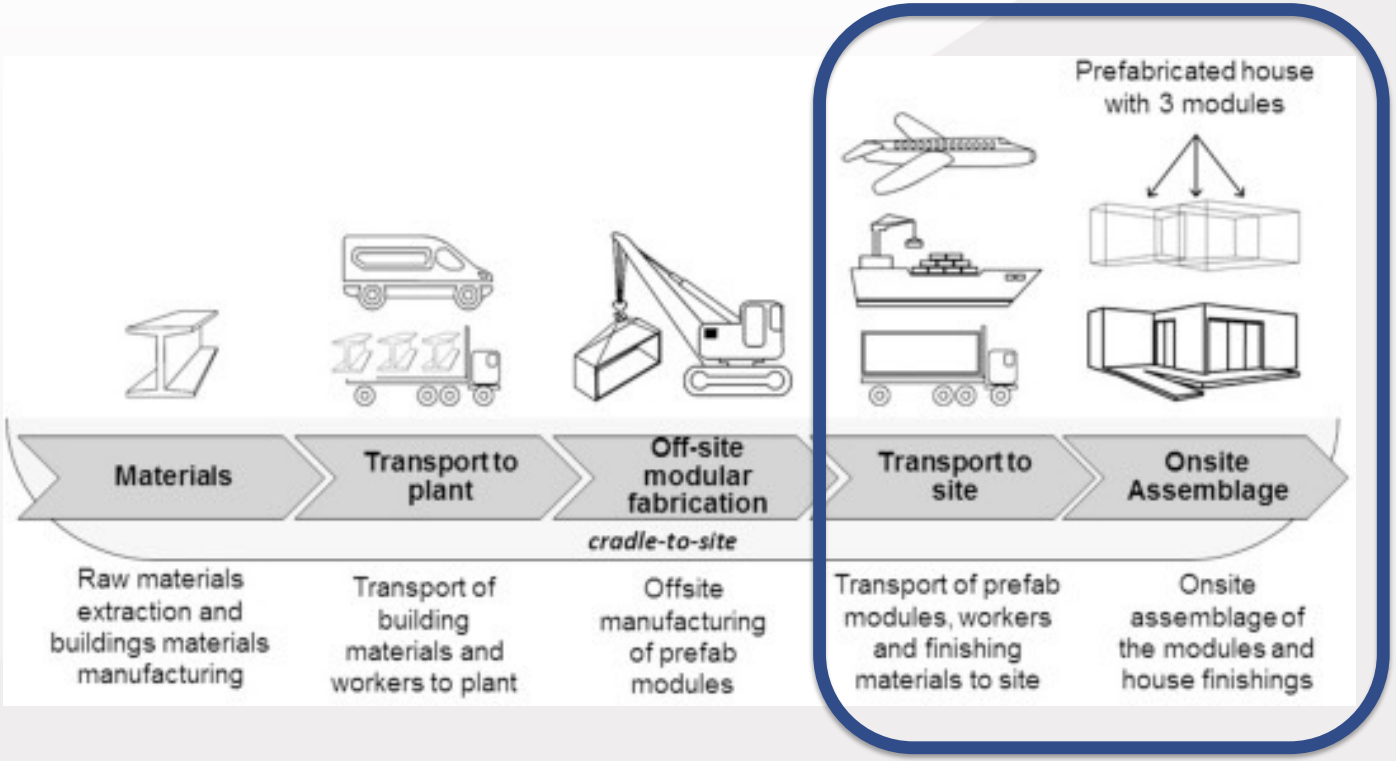
What is “Onsite”?



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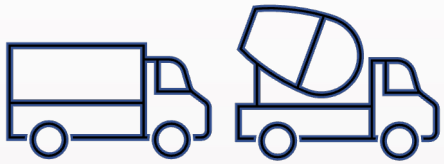
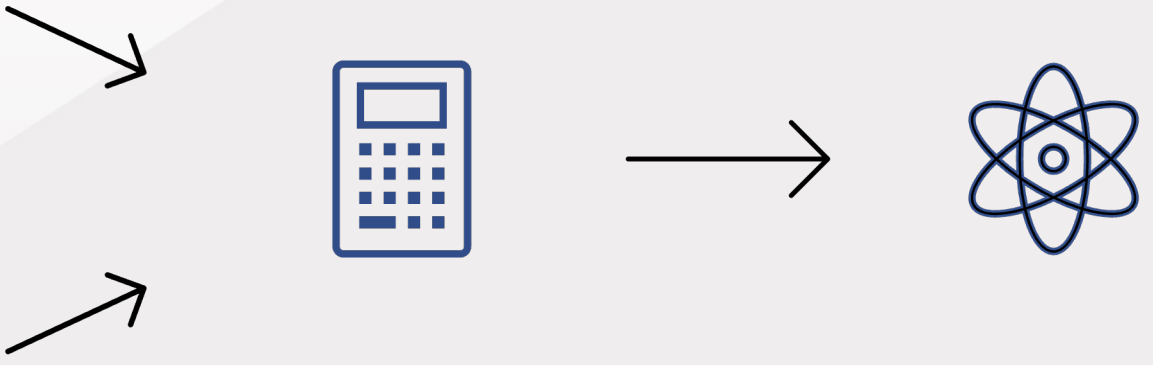
Strategy



Transportation

Construction Equipment



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$$8.0\ hrs_{(Air\ Compressor)} \times 3\ {gal_{fuel}}/{hr} \times 8.5\ {kgCO_2}/{gal_{fuel}} \approx 204\ kgCO_2$$

Activity Duration	Fuel Rate	Carbon Coefficient	Total CO_2 Emissions

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Tranportation Analysis

Option 0: Woolsey

Total Costs: $1,001.40
Total CO2 Emissions: 3114 kg

Enter Transportation Information Here

Vehicle	Material/Equipment Transported	Amt Transported (yd^3)	Transport Origin	Distance from Site (mi)	Amt per Trip (yd^3)	Number of Trips	Number of One-way Trips	Total Miles (full-load) (mi)	Total Miles (empty-load) (mi)
							0	0	0

Onsite Activity Analysis

Option 0: Woolsey

Total Costs: $ 997.33
Total CO2 Emissions: 3102 kgCO2

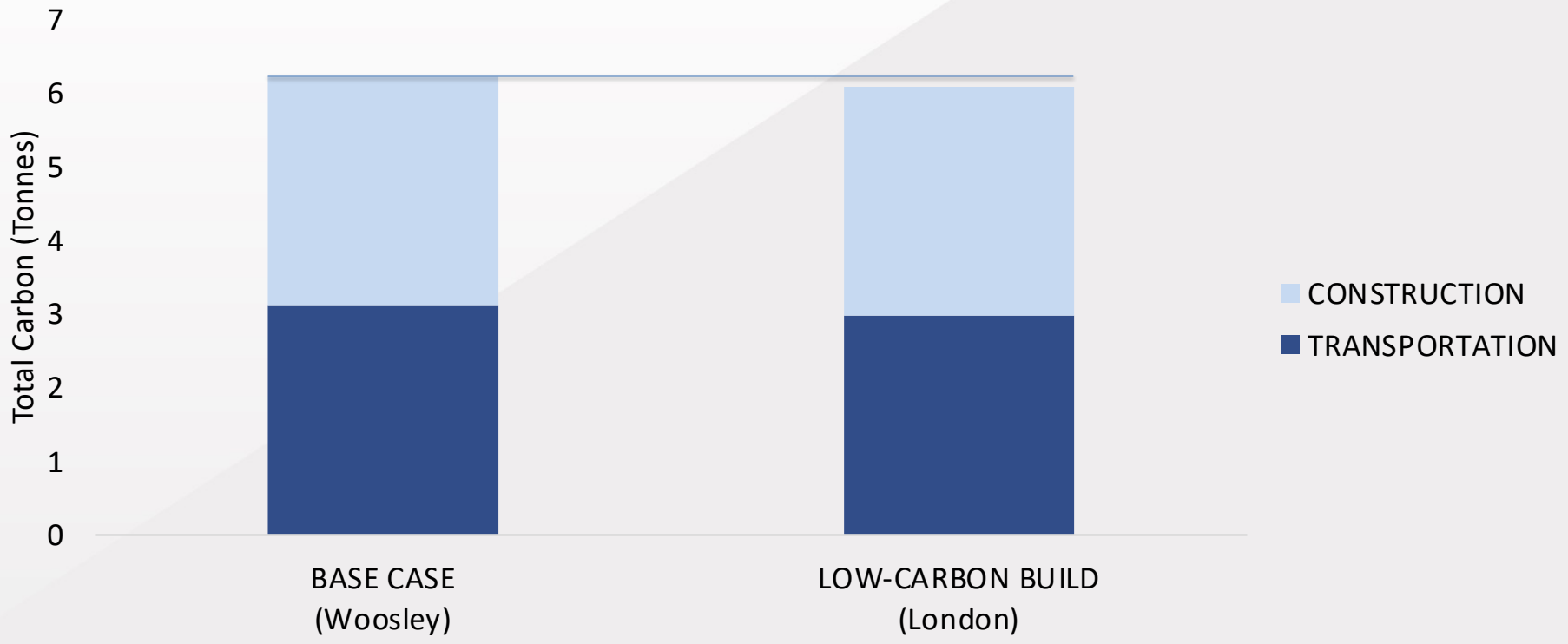
Enter Onsite Activity Information Here

Activity	Machine	Hours/Day	Days/Week	Weeks	Total Time (hrs)	Fuel Rate (gal/hr)	Fuel Type	Fuel amt (gal)	Fuel Cost ($/gal)	Total Cost	CO2 Emission Rate (kg/gal)	Total CO2 Emissions (kg)	Notes
							Diesel	0	3.24	0	10.19	0	

Activity	Machine	Hours/Day	Days/Week	Weeks	Total Time (hrs)	Fuel Rate (gal/hr)	Fuel Type	Fuel Amt (gal)	Fuel Cost ($/gal)	Total Cost ($)	CO2 Emission rate (kg/gal)	Total CO2 Emissions (kg)	Notes
Excavation	Kobelko SK170	8.5	1	1	9	5.0	Diesel	43	$ 3.24	$ 137.70	10.19	433	
Excavation (backfill)	Kobelko SK170	5.5	1	1	6	5.0	Diesel	28	$ 3.24	$ 89.10	10.19	280	
Generating Electricity	Generator	8.0	4	9.5	304	0.5	Diesel	152	$ 3.24	$ 492.48	10.19	1549	
Concrete Pump	Schwing WP 750-1BX	3.0	3	1	9	0.9	Diesel	8	$ 3.24	$ 25.95	10.19	82	
Stone Slinger 1	-	N/A	N/A	N/A	N/A	10.0	Diesel	1	$ 3.24	$ 3.24	10.19	10	
Stone Slinger 2	-	N/A	N/A	N/A	N/A	10.0	Diesel	1	$ 3.24	$ 3.24	10.19	10	
Air Compressor	-	8.0	1	1	8	3.0	Gasoline	24	$ 3.16	$ 75.84	8.50	204	
Crane	-	3.0	1	1	3	0.8	Diesel	2	$ 3.24	$ 7.78	10.19	24	Small crane to lift trusses (mounted on small truck) [3 Hours]
driveway poured		10	1	1	10	5	Diesel	50	$ 3.24	$ 162.00	10.19	510	

6	10	Diesel	0.56	$3.27	$1.83	10.19	6		
3.4	3.4	Diesel	7.647058824	$3.27	$25.01	10.19	78		
6	10	Diesel	1.84	$3.27	$6.02	10.19	19		
8	8	Diesel	3	$3.27	$9.81	10.19	31		
3.4	3.4	Diesel	5.882352941	$3.27	$19.24	10.19	60		
15	15	Diesel	10.67	$3.27	$34.89	10.19	109		
15	15	Diesel	0.27	$3.27	$0.87	10.19	3		
15	15	Diesel	3.47	$3.27	$11.34	10.19	35		
15	15	Diesel	0.27	$3.27	$0.87	10.19	3		
15	15	Diesel	4.80	$3.27	$15.70	10.19	49		
15	15	Diesel	0.07	$3.27	$0.22	10.19	1		
15	15	Diesel	0.27	$3.27	$0.87	10.19	3		
15	15	Diesel	4.67	$3.27	$15.26	10.19	48		
15	15	Diesel	0.27	$3.27	$0.87	10.19	3		
15	15	Diesel	0.35	$3.27	$1.13	10.19	4		
15	15	Diesel	0.27	$3.27	$0.87	10.19	3		

Onsite Carbon Emissions Comparison



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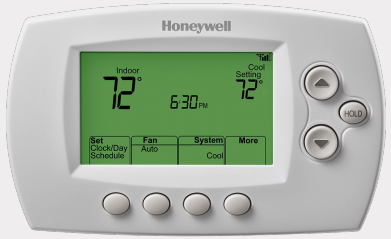
What are “Utilities”?

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



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Utilities – Fundamentally Different

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

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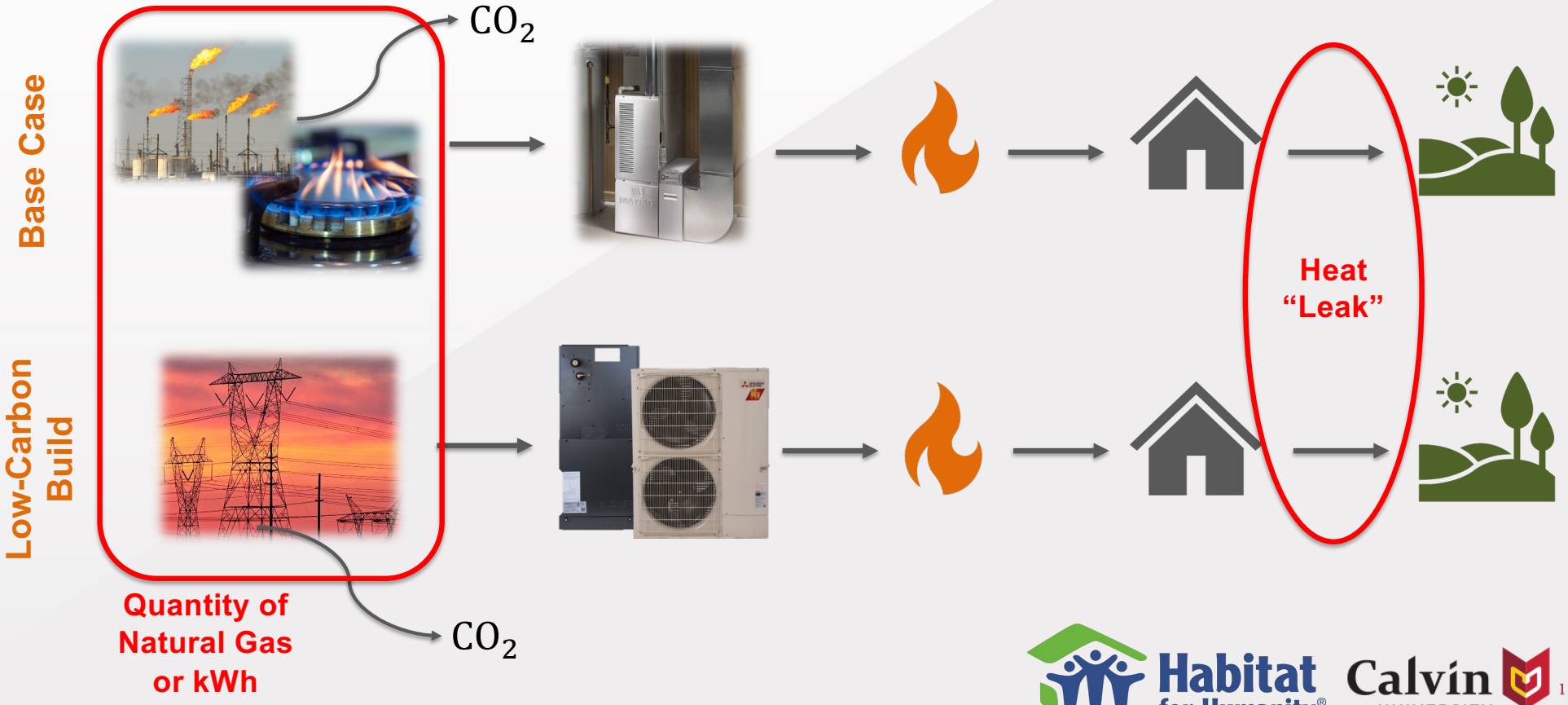
Heating Analysis Procedure



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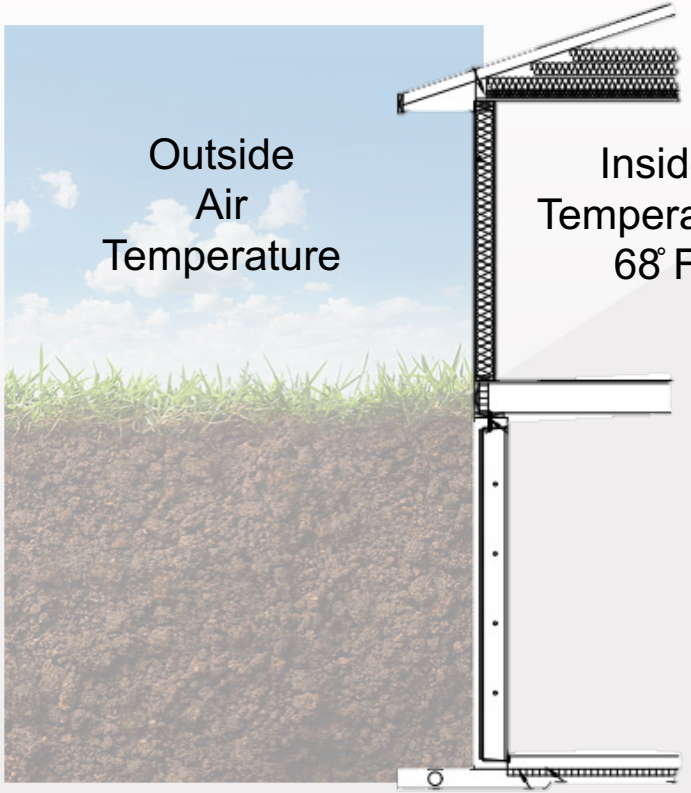
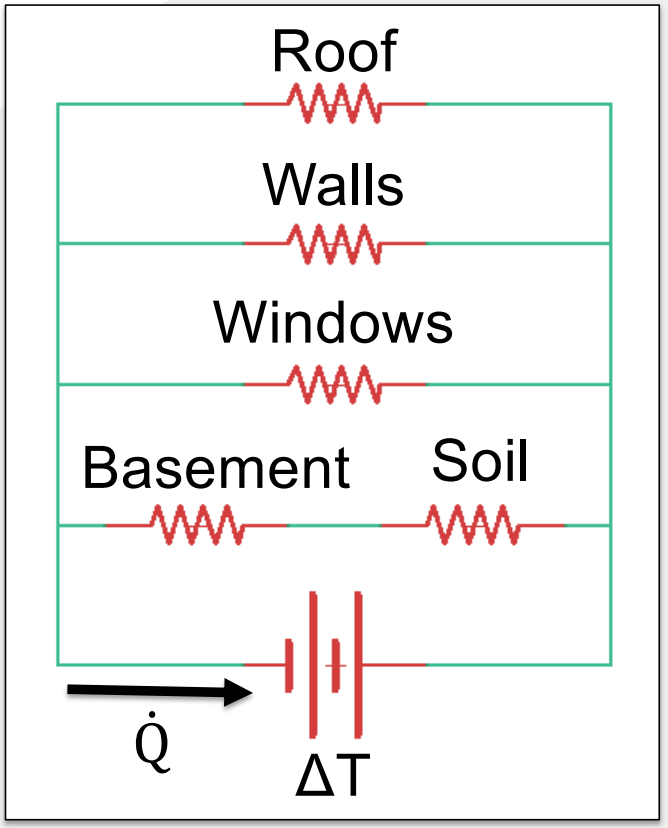
Thermal Resistance Model – "Leak"





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Thermal Resistance Model

Ohm's Law

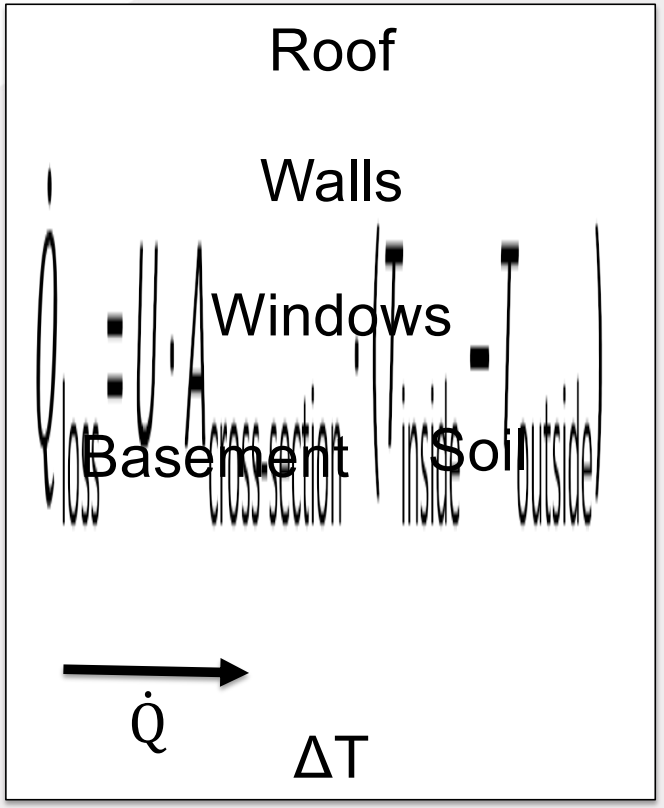
$I = \Delta V / R$

$\Delta V \sim \Delta T$ (Heating Degree Day)

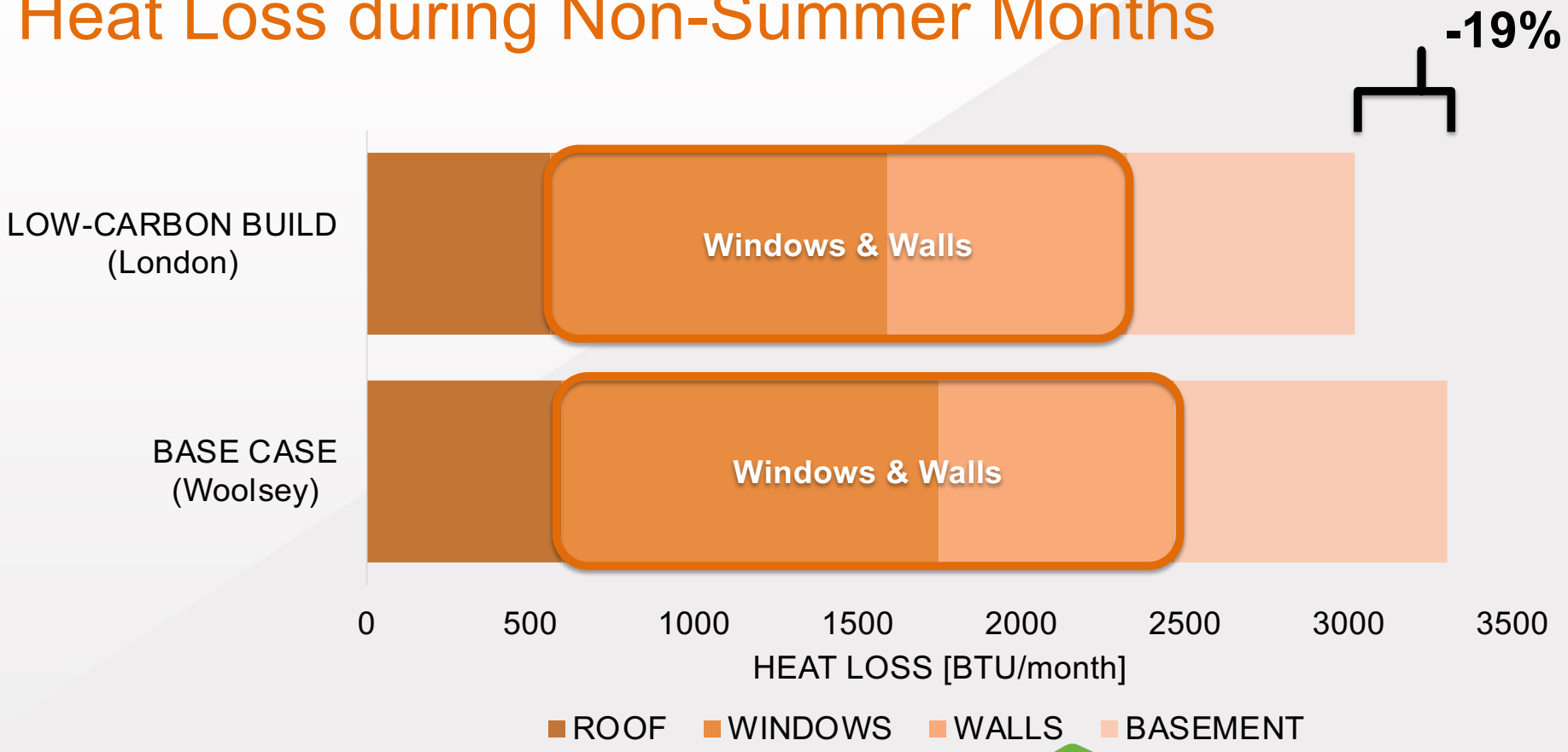
$R \sim 1 / (U \cdot A)$

Thermal Equation:

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



Heat Loss during Non-Summer Months



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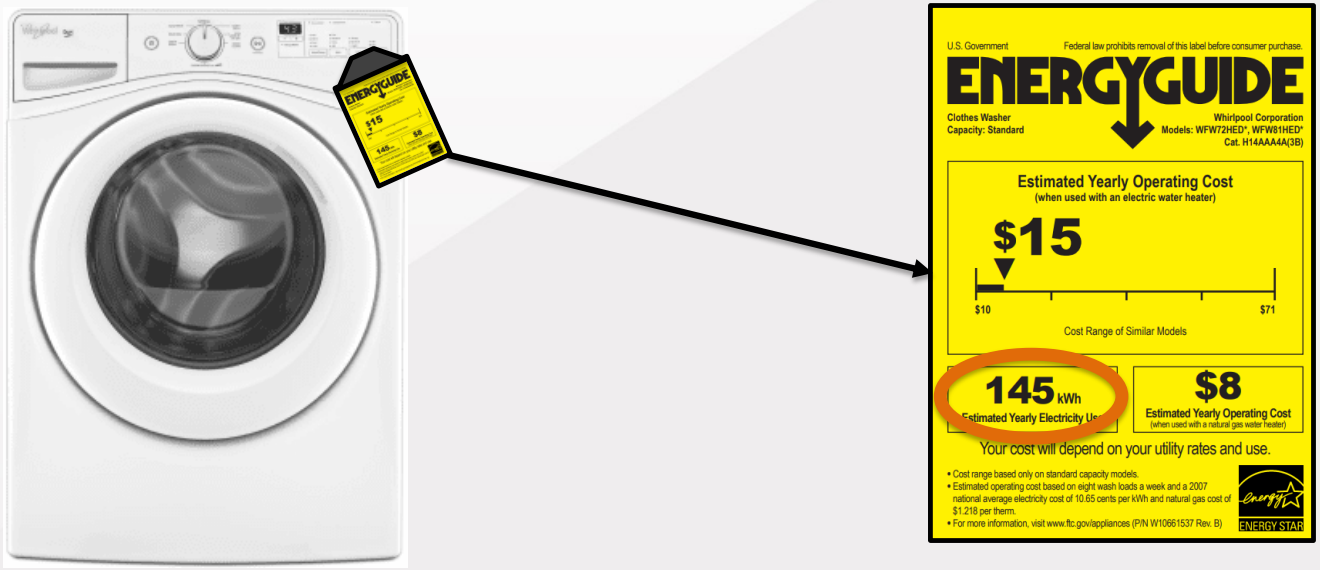
Appliances Procedure



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Appliances Procedure

Range (Stovetop & Oven)

Water Heater

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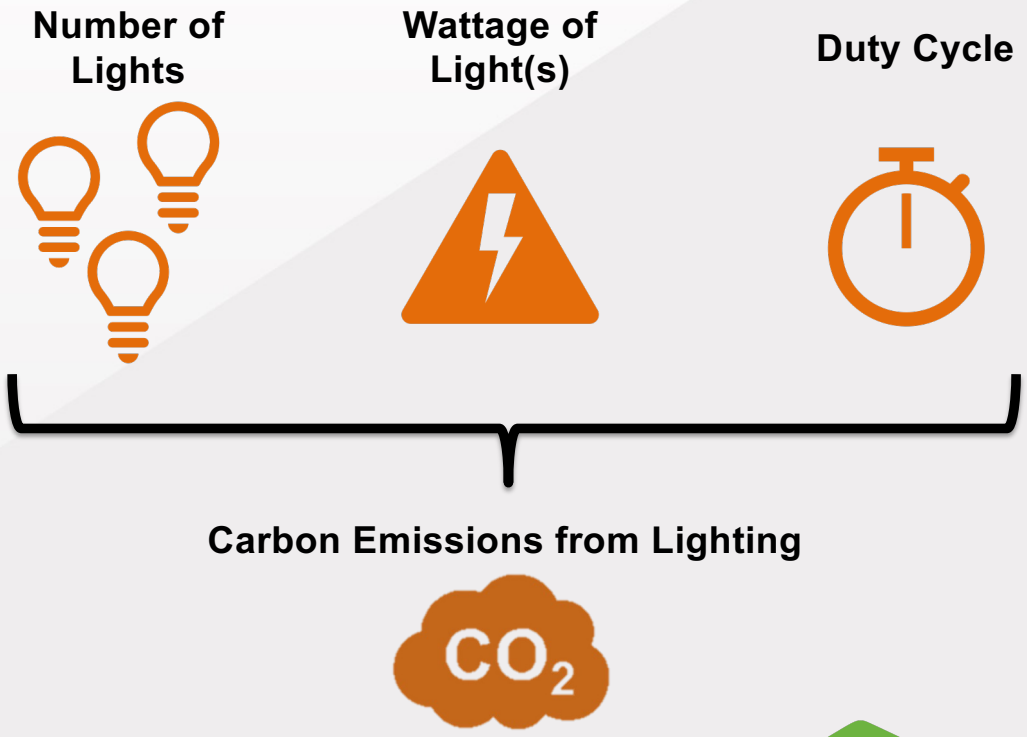
Lighting Procedure



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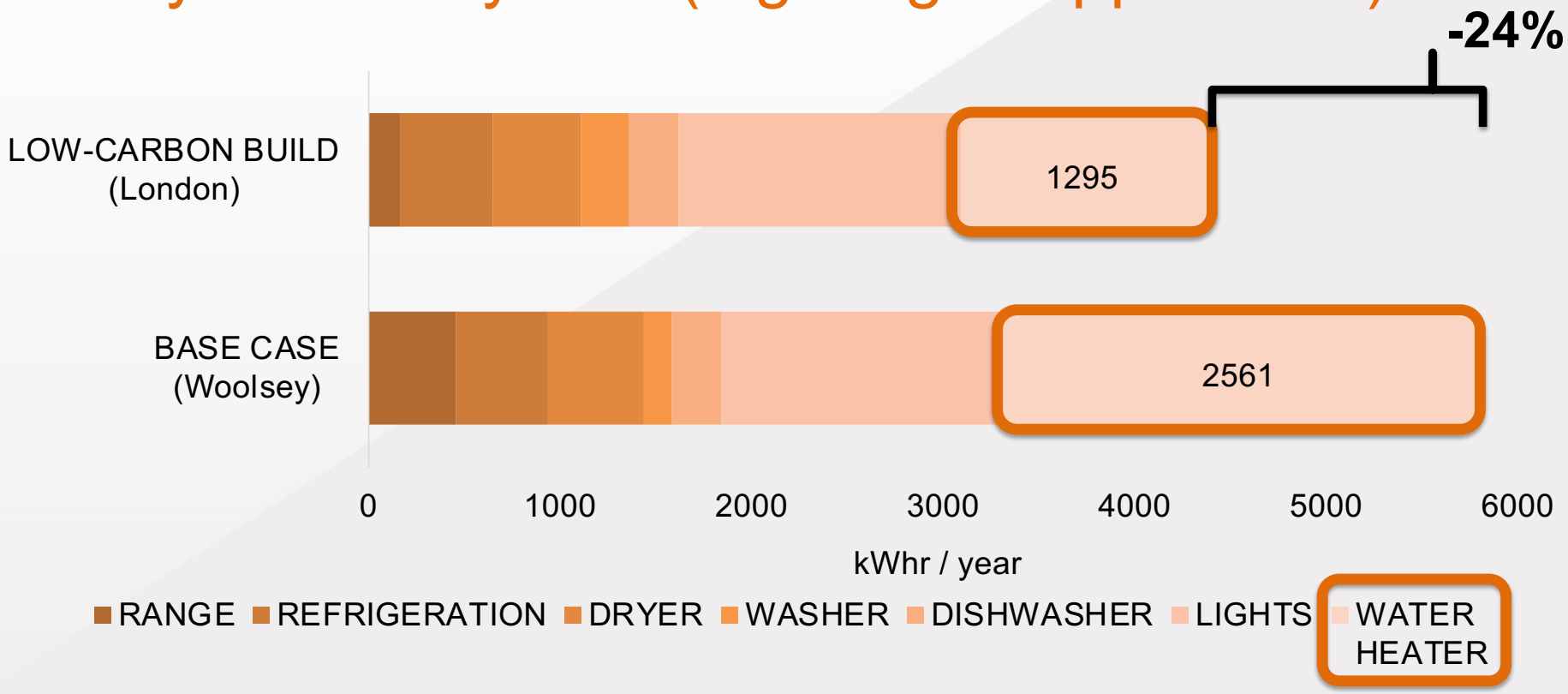
Yearly Electricity Use (Lighting & Appliances)



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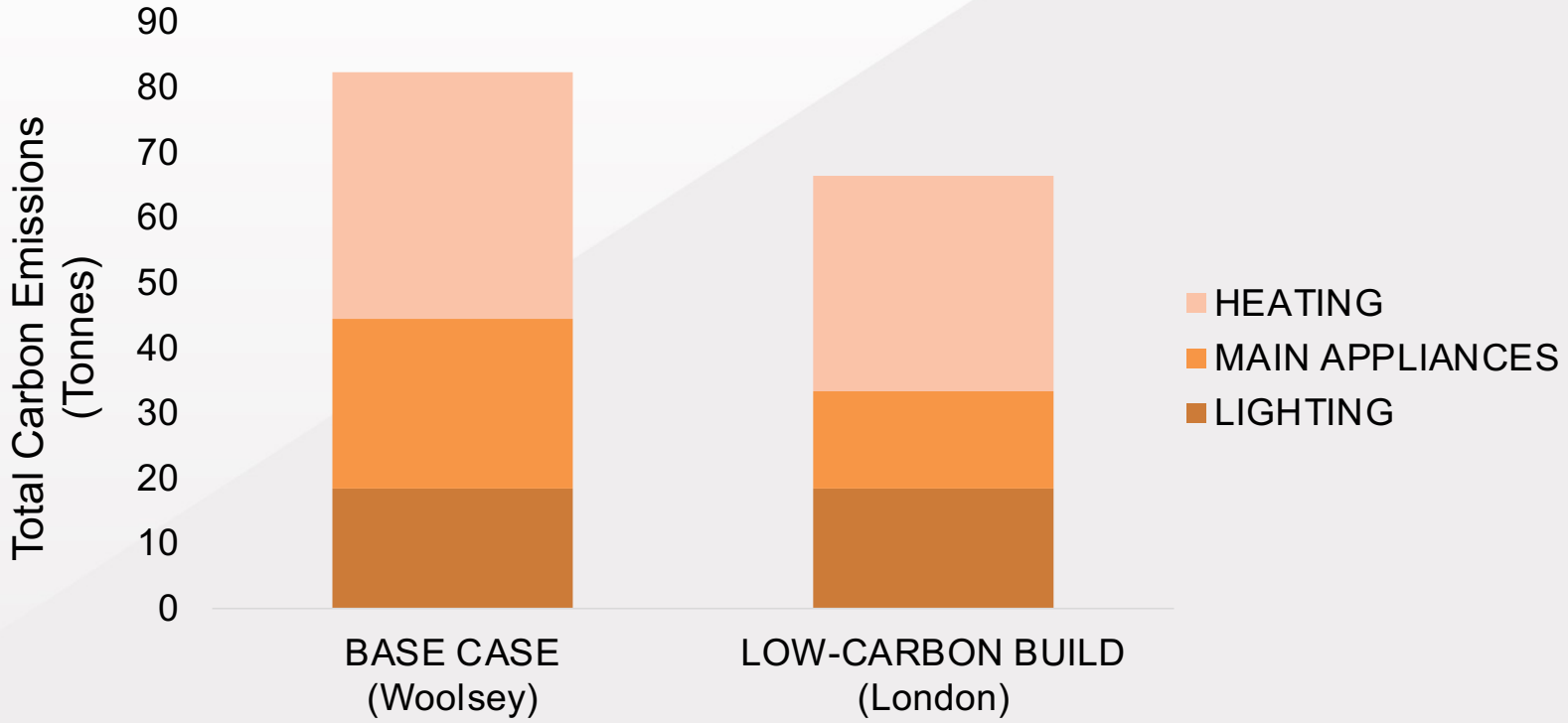
Carbon Emissions from Utilities



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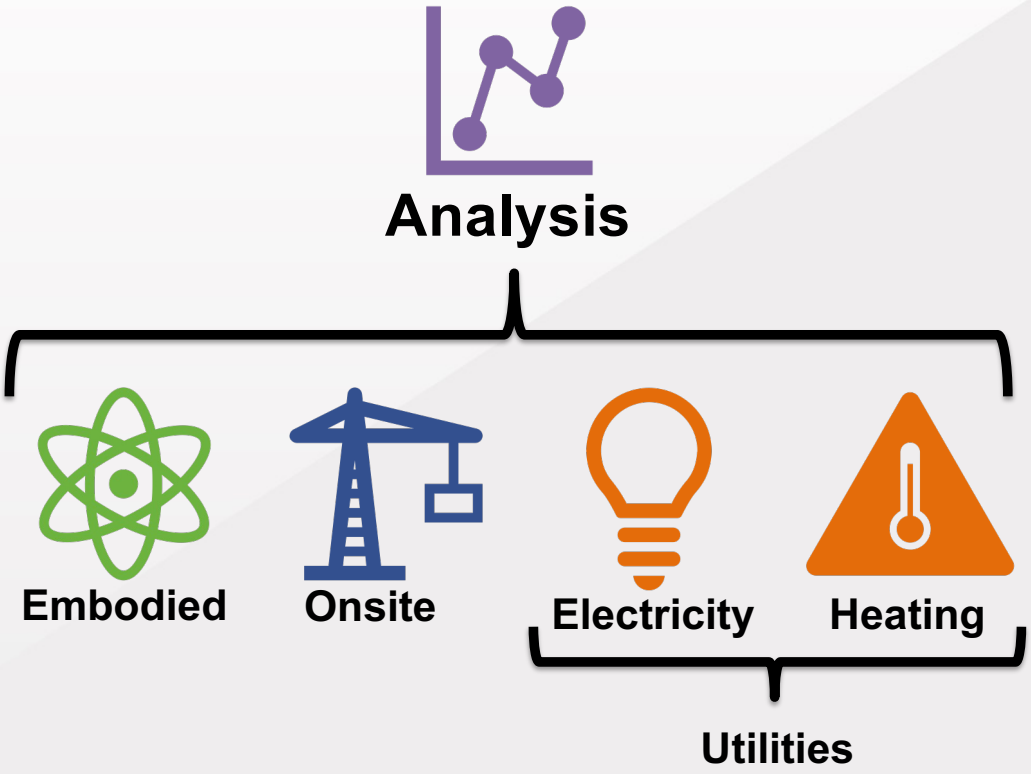

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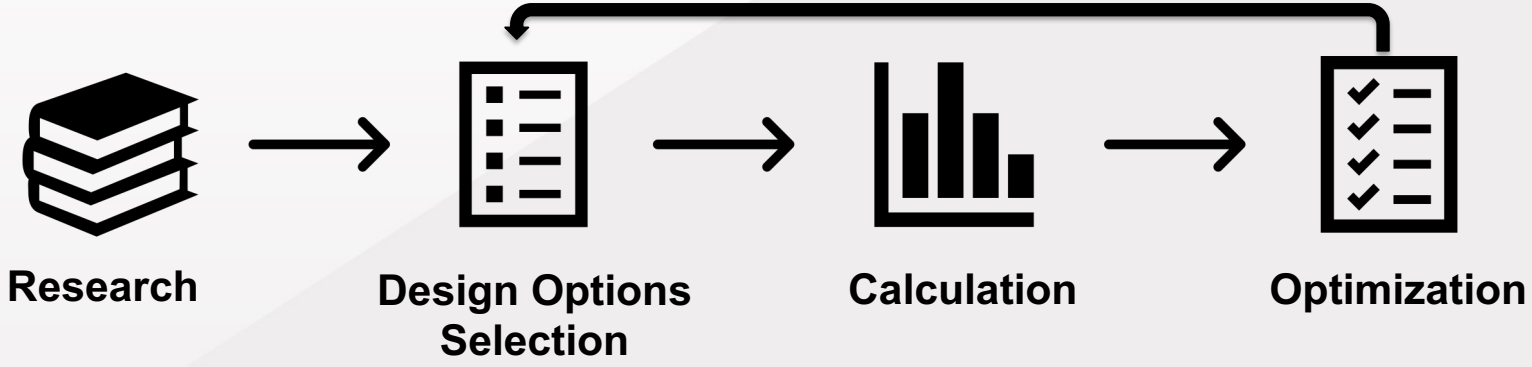
Strategy



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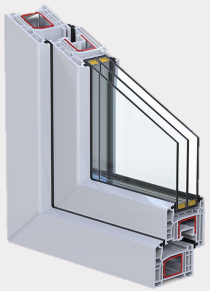
Design Options

Prefabricated Concrete Basement

10 x 425-Watt Solar Panels

Solar Water Heater



Triple Pane Windows

Insulation – type and thickness (6x)

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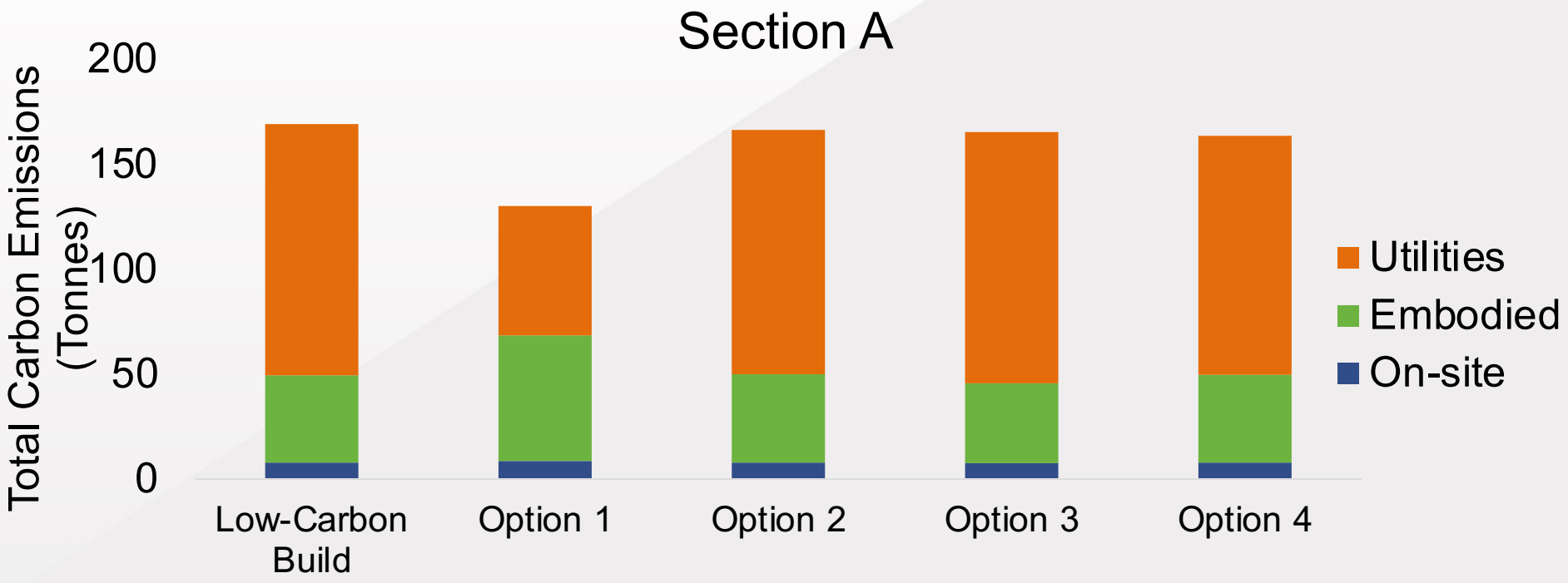
Low Carbon Design Options



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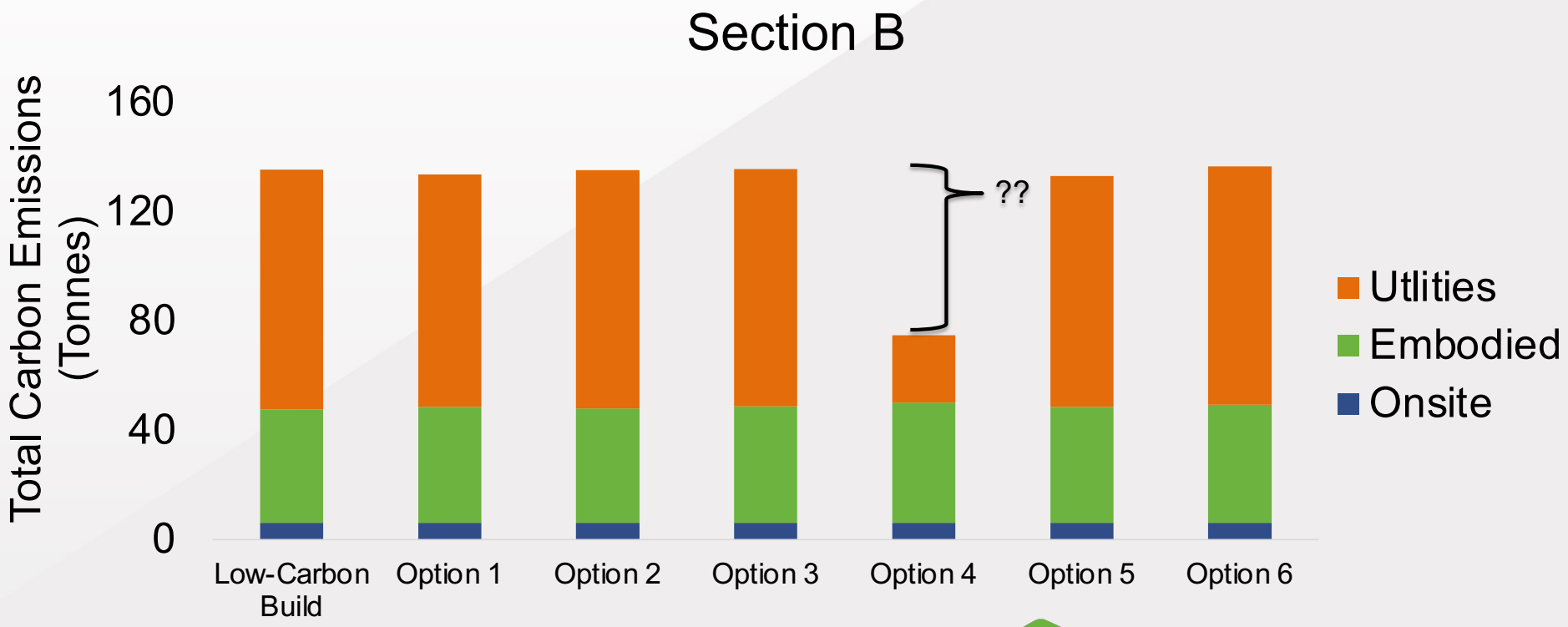
Low Carbon Design Options



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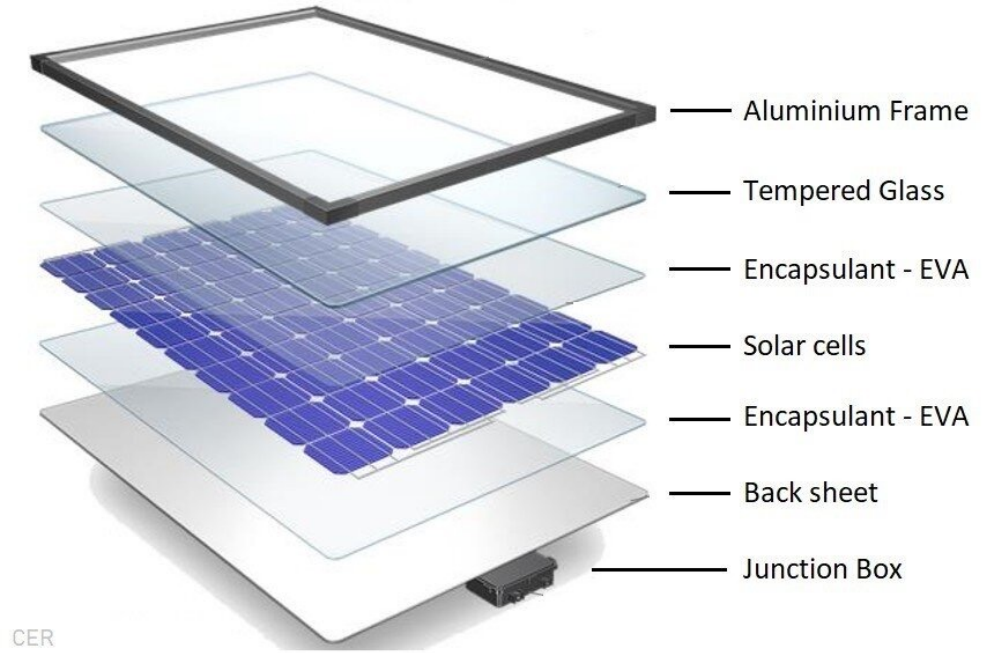
Solar Power Tradeoffs

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



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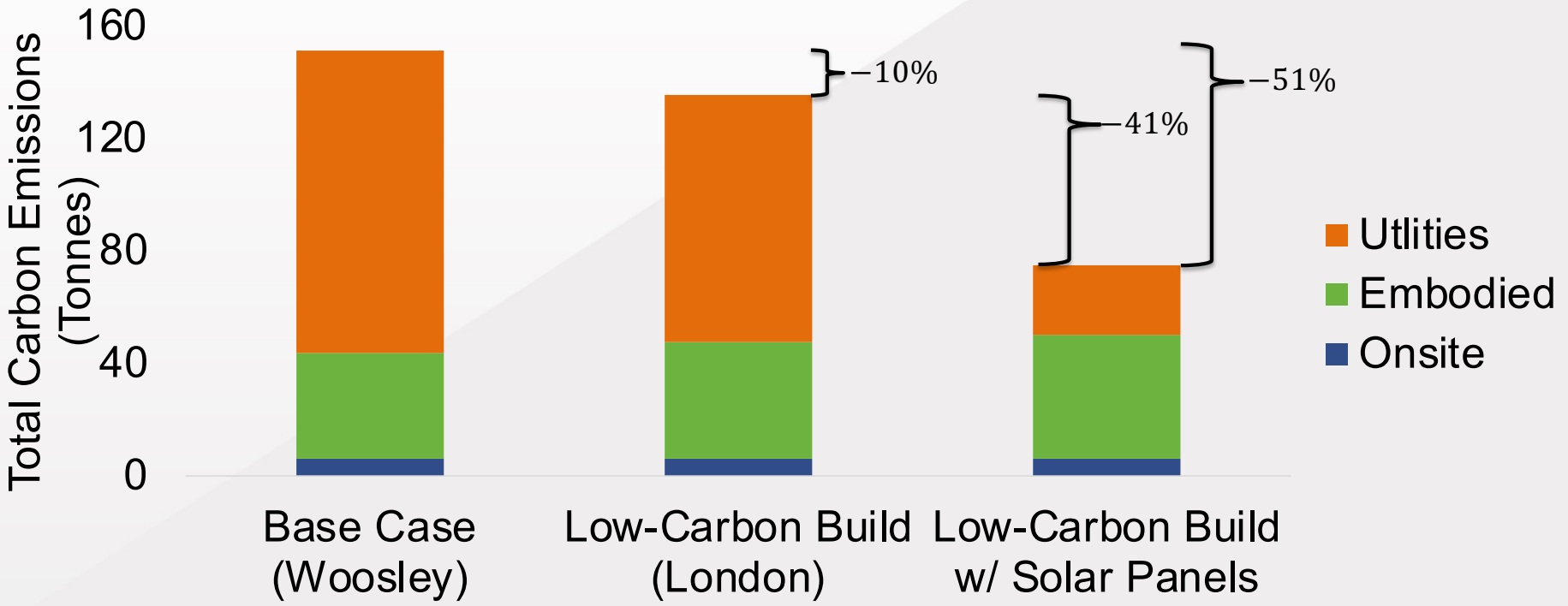
Studied Home Comparisons



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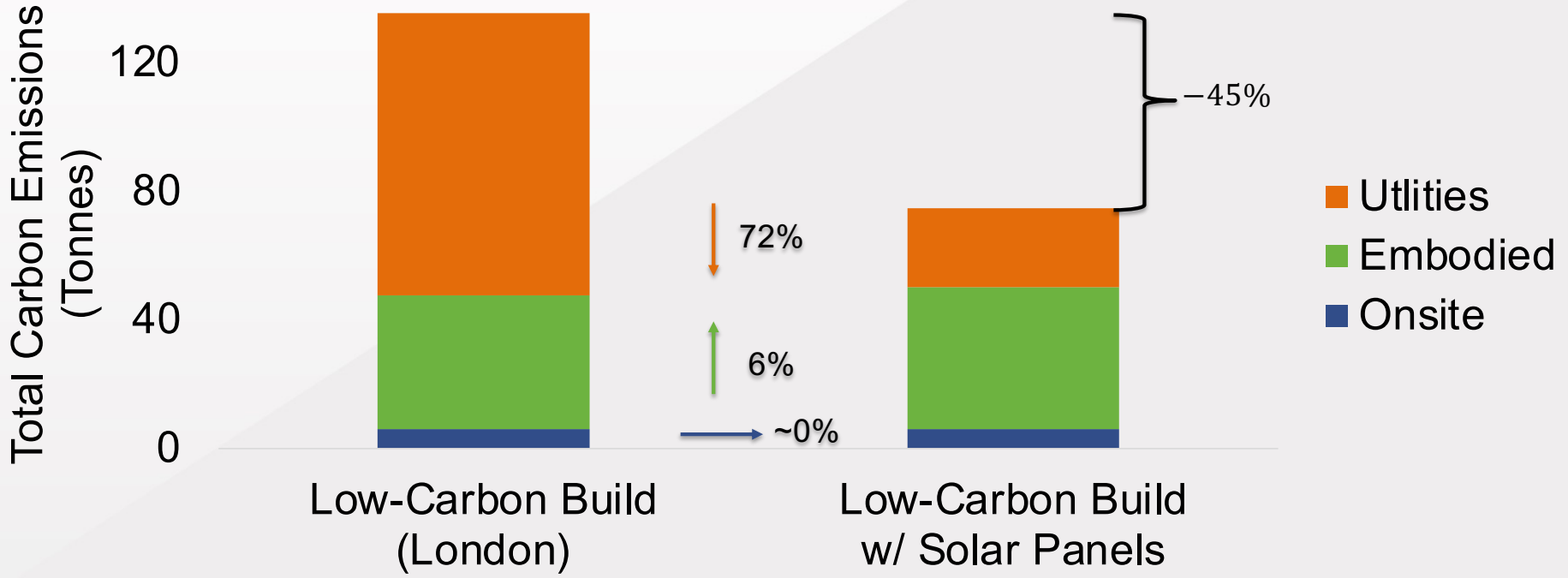
Studied Home Comparisons



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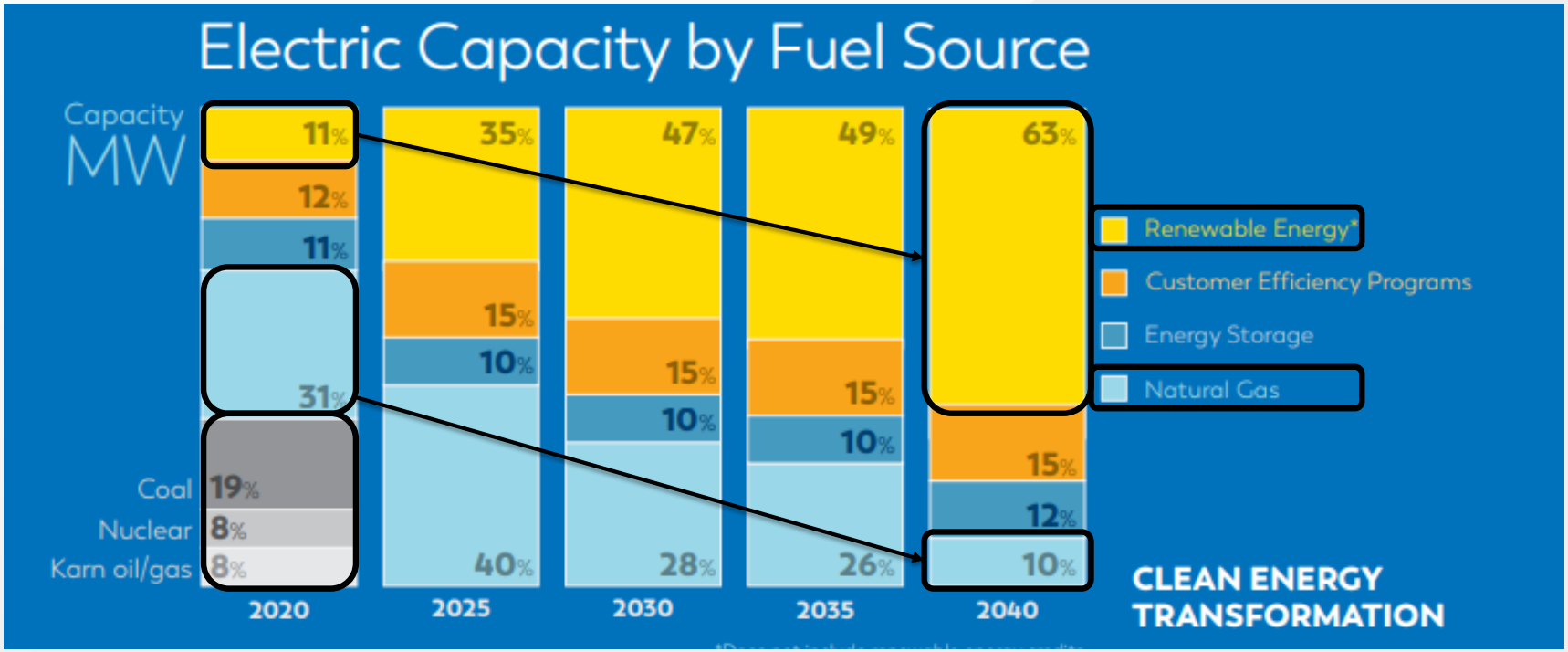
Consumers' Clean Energy Grid



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

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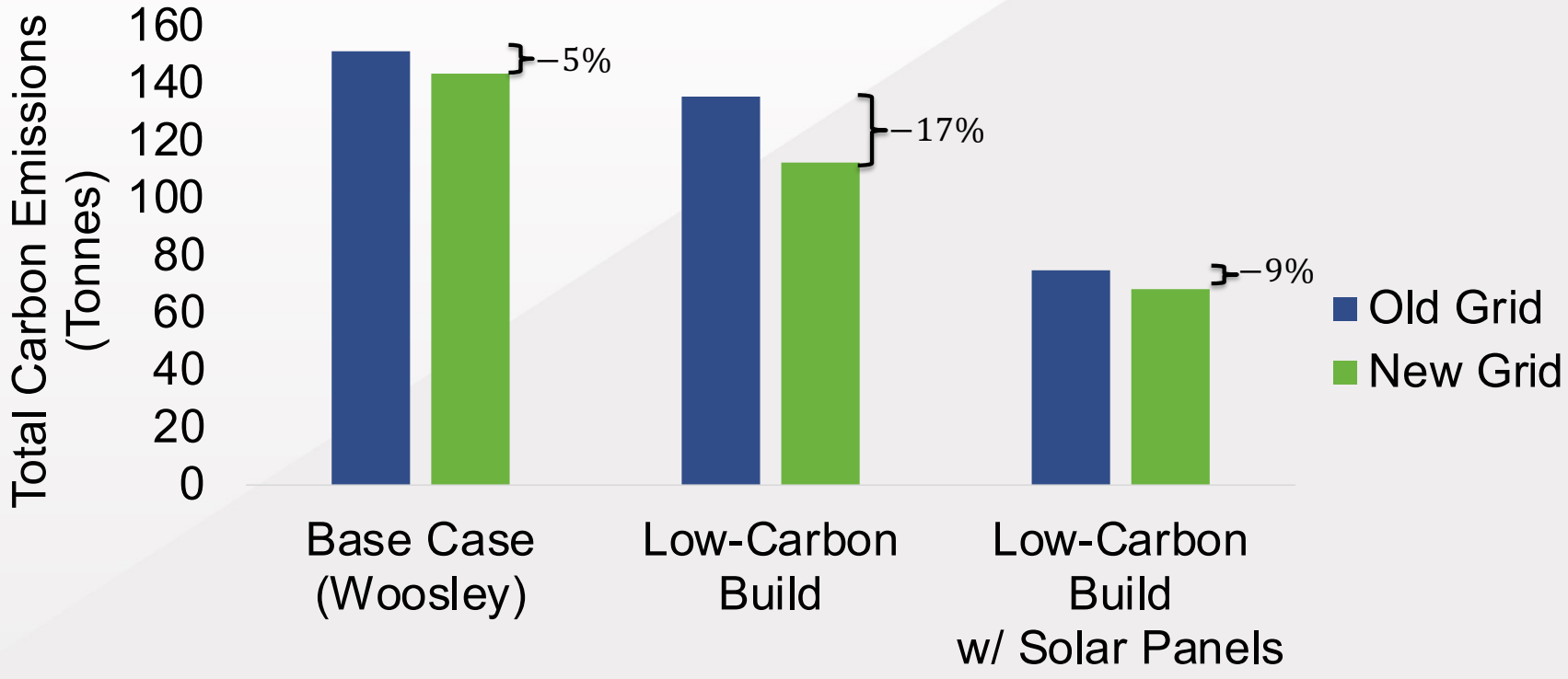
Clean Energy Grid Impacts



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Future Directions

- Financial Analysis
- Additional design options

Honorable Mentions

- Prefab Basement → -4%
- Solar Water Heater → -6%
- Triple Pane Windows → -3%
- Increased Insulation → -3%

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Lessons Learned

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

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Special Acknowledgements

John Marek

Mark Ogland-Hand

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Questions

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