## Low-Carbon Housing Project

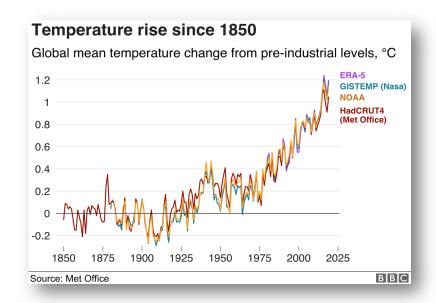
Speakers: Anika Huizinga, John Stehouwer, William Terpstra, Duncan Waanders
Engineering Seminar SB010 | December 1<sup>st</sup>, 2021
Presented by Engineering 333



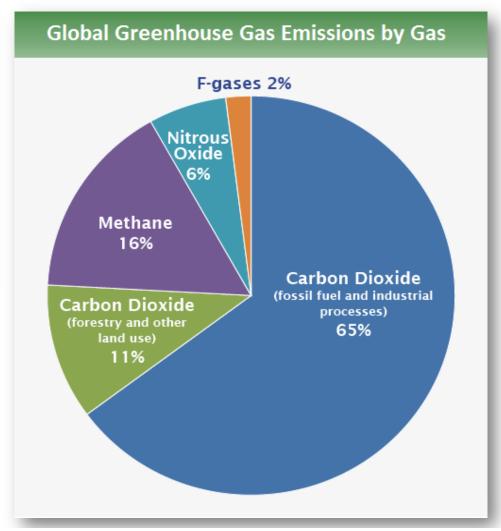
### Outline

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









#### U.S. energy-related carbon dioxide emissions (1980-2020) billion metric tons by end-use sector by source 6 6 5 5 transportation petroleum 4 4 3 3 industrial natural gas 2 2 residential 20% 1 1 coal commercial

1980

2020

1990

2000

2010

2020

0

1980

1990

2000

2010

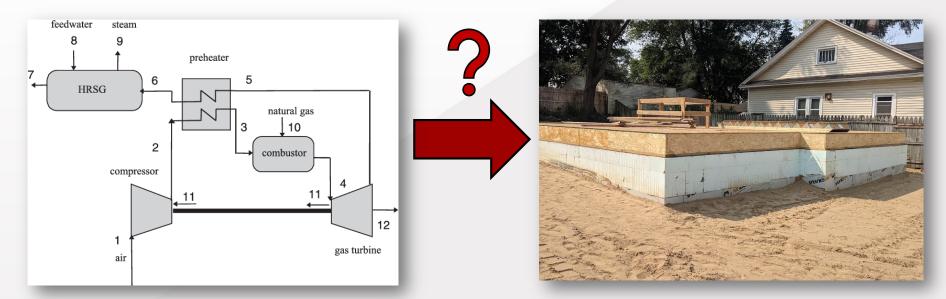


#### Project Introduction – 08.31.2021

- 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



#### Sections



**Section A** 

Case Study: 536 Stolpe St SW



**Section B** 

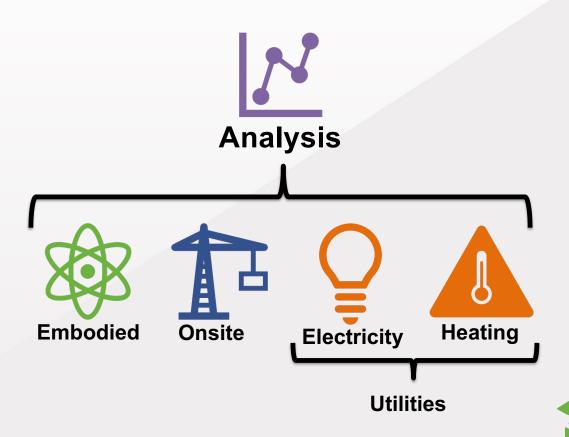
Case Study: 930 Woolsey Dr SW

#### **Both Sections:**

Low-Carbon Build: 726 London St SW



### **Section Organization**







#### **Progress Updates**

- Status to Schedule
- Work Accomplished
- Issues / Concerns
- Work Planned

Each team member presented

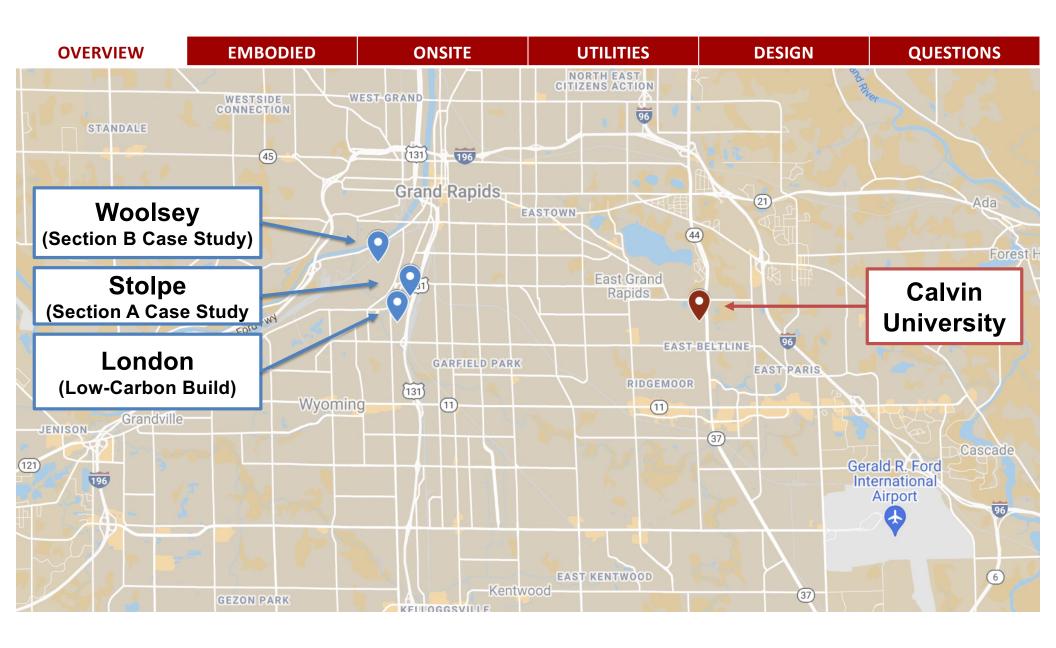
Mark Ogland-Hand (Client)



Professor Heun (Consultant)







**Section A** 536 Stolpe Ave



**Section B** 930 Woolsey SW





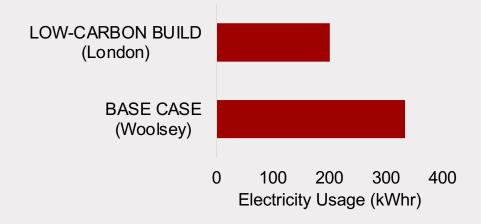


#### Note on Charts and Units

## Vertical Bar Charts: Carbon Emissions



# Horizontal Bar Charts: Usage Rates



#### **Carbon Emission listed as Metric Tonnes**

 $(1 \text{ Tonne} = 1000 \text{ kg} \neq 2000 \text{ lbs})$ 



#### London: Low-Carbon Build House

Insulated Concrete Forms Foundation

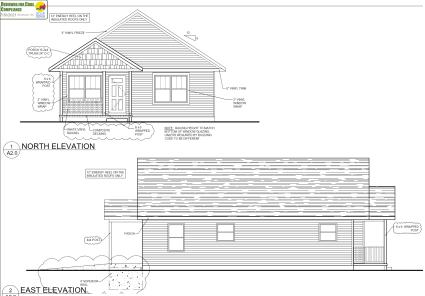
#### All Electric

- Heat pump
- Water Heater(Rather than Generate Heat)

**Move Heat** 

Other Appliances





#### **London Progress**

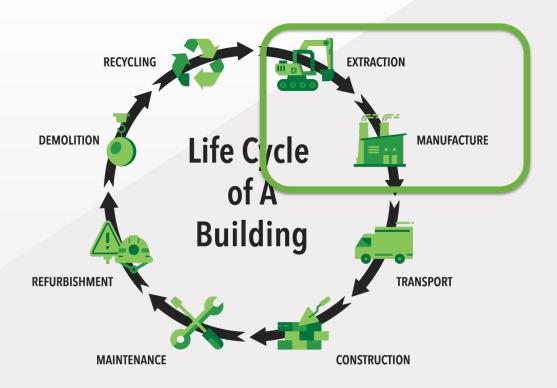


09/07/2021

11/13/2021



#### What is "Embodied"?



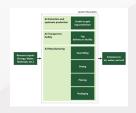


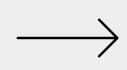
### Strategy



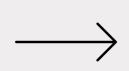
Inventory of Carbon and Energy













Environmental Product Declaration



Embodied Carbon in Construction Calculator





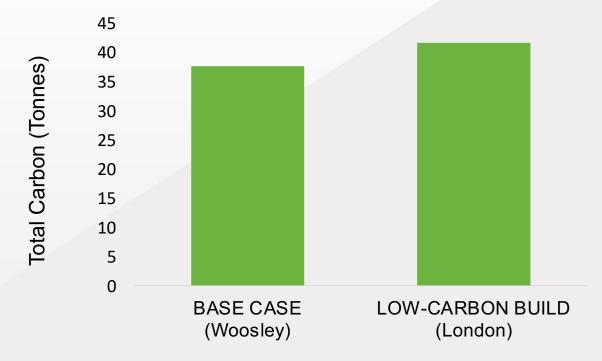
OVERVIEW	EMBODIED	ONSITE	UTILITIES	DESIGN	QUESTIONS
Outdoor Concrete	$\times$ 22.5 $yd^3$	×	$320 \frac{kgCO_2}{yd^3}$	≈ ≈	$7000~kgCO_2$
Material		Quantity	Carbon Coefficien	t	Total Embodied Carbon



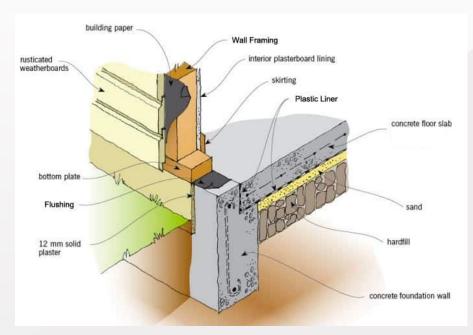
Material/House Porti	o Quantity:	(Units	Embodied carbon per un	(Units)	Total Embodied Carbon (kgCO2)	Emitted Carbon	:
Outdoor Concrete	25	yd3	320	kgCO2/yd3	8000	41,599.49	kgCO2
Foundation:			Components Below:		-		
-exterior walls	16	m3	420	kgCO2/m3	6720		
-footing	4.5	m3	420	kgCO2/m3	1890		
-flooring	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		Comp	ponents In Siding Work Sh	eet	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/Ib	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		kgCO2/m	375		
Plumbing	200	lb		kgCO2/Ib	236		



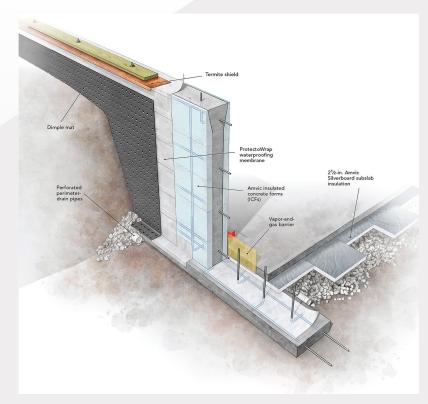
### **Embodied Carbon Comparison**







**Poured Concrete** 



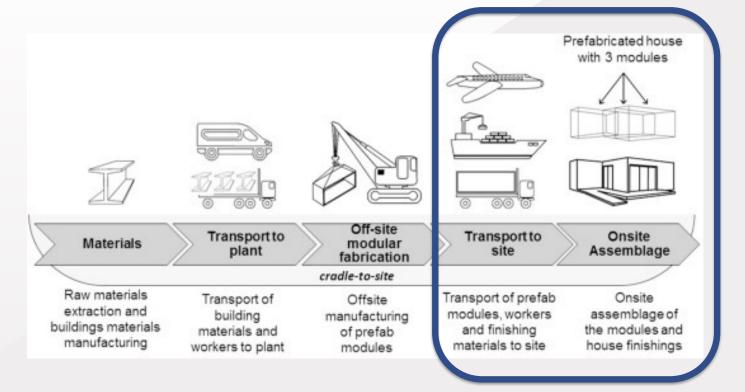
Insulated Concrete Forms (ICF)







#### What is "Onsite"?





### Strategy



Transportation

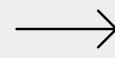


**Construction Equipment** 













 $8.0\ hrs_{(Air\ Compressor)} \ imes \ 3^{\ gal_{fuel}}/_{hr} \ imes \ 8.5^{\ kgCO_2}/_{gal_{fuel}} \ pprox 204\ kgCO_2$ 

Activity Duration

Fuel Rate

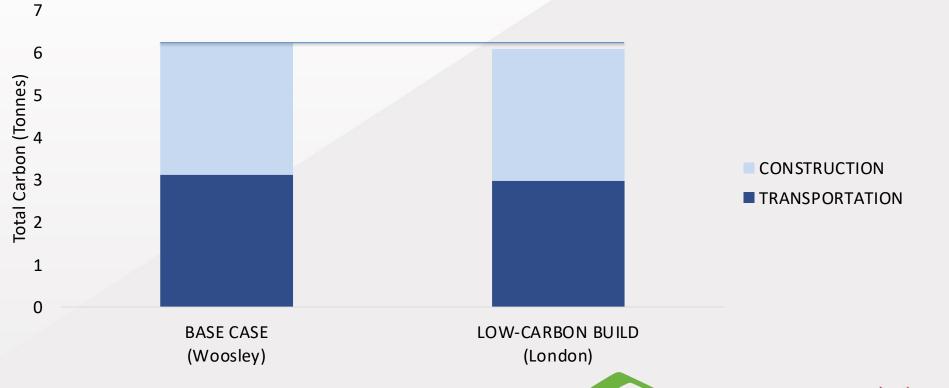
Carbon
Coefficient

Total CO<sub>2</sub>
Emissions



Section   Sect							_								
Company   Comp	OVERVIEW	V	EN	ивоі	DIED			ONSITE	Ξ		UTILI	TIES		DESIGN	QUESTIONS
March   Marc		Tranporta	tion Analysis												
Ministration   Mini	,	Total Costs:		_		1,001.40									
Company   Comp															
Second Code   S				Material/Eq	uipment Transpo	orted A	nt Transported (yd³)	sported (yd²) Transport Origin Distance from Site (mi) Amt per Trip (yd²) Number of Trips Nu					of Trips Number of One-way Trips	Total Miles (full-load) (mi) 0	Total Miles (empty-load) (mi) 0
Second Code   S								•		•			<u> </u>	<del> </del>	<u>.</u>
Machine   Mountain How   Mountain	Onsite Activity Analy	sis													
Machine   Mach	Total Costs: Total CO2 Emissions:	\$	997.33 3102	kgCO2											
Selection Nation National Process (1)	Enter Onsite Activity Information Here	Ma	ahin a	Harris (Day)	Dave March	Meska	Total Time (bus)	Fuel Date (mal/ha)	Fuel Tone	Fuel and (nell)	Fuel Coat (\$(sel)	Total Coat	CO2 Emission Boto (ke/mal)	Total CO2 Emissions (Iva)	Notes
Scene   Scene   Scene   Str	Activity	Mac	Cillie	nours/Day	Days/week	veeks	Total Time (HFS)	ruel Rate (gal/nr)	Diesel	ruerami (gal)	3.24	Cost	10.15	)	
Scene   Scene   Scene   Str	Activity	Mad	chine	Hours/Dav	Davs/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
Schwing Mile 759-19X   2,00   3   1   0   0   0   0   0   0   0   0   0	Excavation	Kob	oelko SK170	8.5	1	1		5.0	Diesel	43	\$ 3,24	\$ 137.70	10.19	433	
Schwing Mile 759-19X   2,00   3   1   0   0   0   0   0   0   0   0   0							6				\$ 3.24	\$ 89.10			
Series   N/A   N	Concrete Pump	Sch	nerator owing WP 750-1RY	3.0			304	0.5	Diesel	152	\$ 3.24	\$ 492.40	10.19	1549	
Series   N/A   N	Stone Slinger 1	-	IWING WIT 750-16X	N/A			N/A				\$ 3.24	\$ 3.24	10.19		
M. Compressor   - 8.0   1   1   8   3.0   Gascher   24   \$   3.10   \$   75.64   8.69   294   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse (mounted on small truck) [5 Hours]   24   Small crare to int trouse [5 Hours]	Stone Slinger 2		-	N/A	N/A	N/A	N/A	10.0	Diesel		\$ 3.24	\$ 3.24	10.19		
1	Air Compressor		-	8.0		1			Gasoline	24	\$ 3.16	\$ 75.84		204	
6 10 Deed 7,4705824 537 548 10.19 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	Crane														Small crane to lift trusses (mounted on small truck) [3 Hours]
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10	*driveway poured*			10	1	1	10	5	Diesel	50	\$ 3.24	\$ 162.00	10.19	510	
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3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10															
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10						1									
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10															
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10															
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10															
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10															
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10															
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10			6		10	Diesel	0.56	\$3.27	\$1.83		10.19	6			
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10			3.4		3.4	Diesel	7.647058824	\$3.27	25.01		10.19	78			
3.4   3.4   Dissel   5.882352941   \$3.27   \$19.44   10.19   60   15   15   Dissel   10.67   \$3.27   \$34.89   10.19   109   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$11.34   10.19   35   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.27   \$3.27   \$0.67   10.19   3   15   15   Dissel   0.07   \$3.27   \$0.22   10.19   49   16   17   Dissel   0.07   \$3.27   \$0.27   10.19   3   17   18   19   19   10   10   18   19   19   10   10   19   10   10   10   10   10   10   10   10	_		6		10	Diesel	1.84	\$3.27	\$6.02		10.19				
15         15 Diesel         10.07         \$3.27         \$3.4.89         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         \$5.70         10.19         3           15         15 Diesel         4.80         \$3.27         \$5.70         10.19         49           15         15 Diesel         0.07         \$3.27         \$0.22         10.19         1           15         15 Diesel         0.27         \$3.27         \$0.27         10.19         3           15         15 Diesel         0.27         \$3.27         \$15.26         10.19         4           15         15 Diesel         0.27         \$3.27         \$10.29         10.19         3           15         15 Diesel         0.27         \$3.27         \$0.87         10.19         3           15         15 Diesel         0.27         \$3.27         \$0.87         10.19         3           15         15 Diesel         0.27         \$3.27 <td>-</td> <td></td> <td>3.4</td> <td></td> <td>3.4</td> <td>Diesel</td> <td>5.882352941</td> <td></td> <td></td> <td></td> <td>10.19 </td> <td></td> <td></td> <td></td> <td></td>	-		3.4		3.4	Diesel	5.882352941				10.19				
15 15 Diesel 4.07 \$3.27 \$13.00 10.19 40 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	10.67	\$3.27	34.89		10.19	109			
15 15 Diesel 4.07 \$3.27 \$13.00 10.19 40 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	Diesel	0.27	\$3.27	\$0.87		10.19				
15 15 Diesel 4.07 \$3.27 \$13.00 10.19 40 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	3.47	\$3.27	\$0.87		10.19	35			
15 15 Diesel 4.07 \$3.27 \$13.00 10.19 40 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	4.80	\$3.27	315.70		10.19	49			
15 15 Diesel 4.07 \$3.27 \$13.00 10.19 40 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	0.07	\$3.27	\$0.22		10.19	1			
15 15 Diesel 4.07 \$3.27 \$13.00 10.19 40 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	Diesel	0.27	\$3.27	\$0.87		10.19	3			
15	_				15	Diesel	4.67	\$3.27	10.20		10.19	48			
15 15 Diesel 0.27 \$3.27 \$0.87 10.19 3	-				15	Diesel	0.27	\$3.27 \$3.27	\$1.67		10.19	3			
					15	Diesel	0.35	\$3.27	\$0.87		10.19				
	_							41							

#### Onsite Carbon Emissions Comparison





#### What are "Utilities"?

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













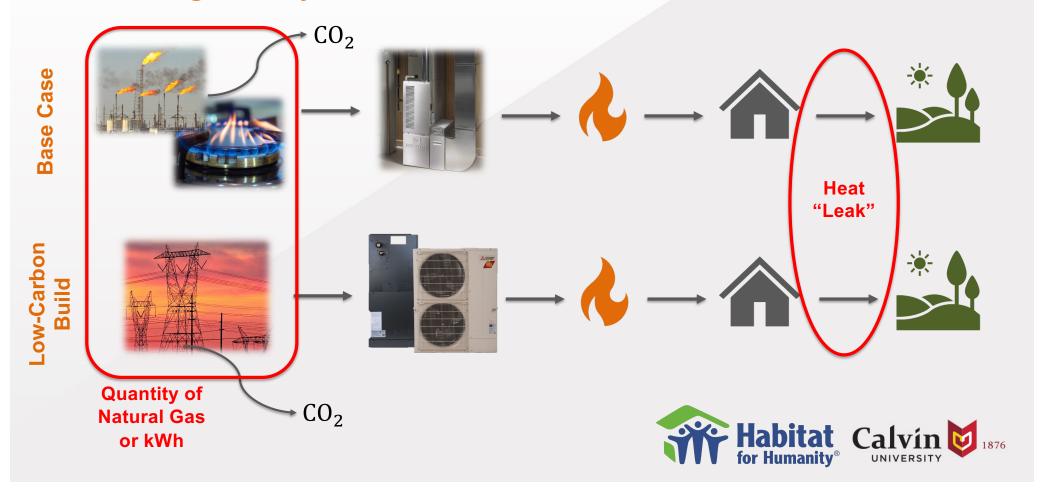


### Utilities – Fundamentally Different

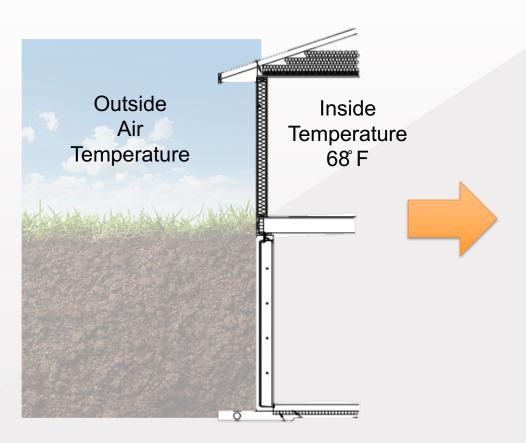
- Embodied & Onsite: One-time
- Utilities
  - Reoccurring annually
  - 25-year period

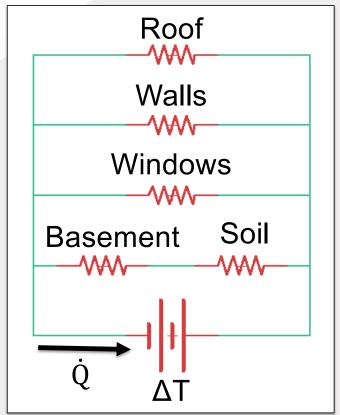


### **Heating Analysis Procedure**



#### Thermal Resistance Model – "Leak"







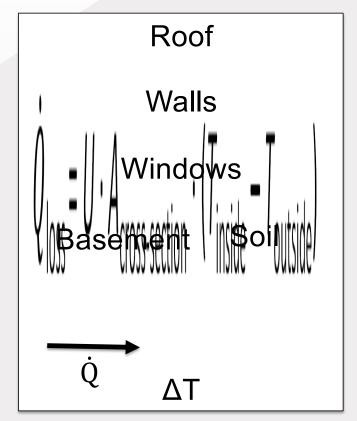
#### **Thermal Resistance Model**

#### Ohm's Law

$$I = \Delta V/R$$
  
  $\Delta V \sim \Delta T$  (Heating Degree Day)  
  $R \sim 1 / (U \cdot A)$ 

#### **Thermal Equation:**

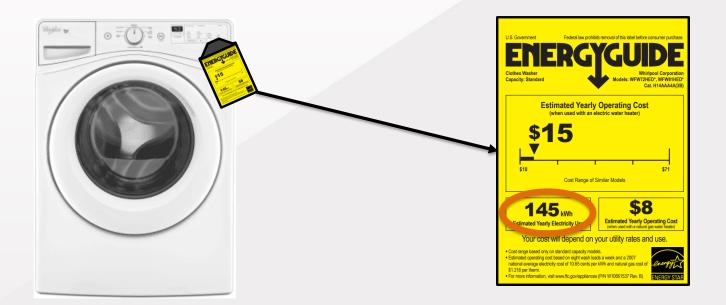
$$\dot{Q}_{loss} = U \cdot A_{cross-section} \cdot (T_{inside} - T_{outside})$$





**OVERVIEW EMBODIED ONSITE QUESTIONS UTILITIES DESIGN** Heat Loss during Non-Summer Months -19% **LOW-CARBON BUILD** Windows & Walls (London) **BASE CASE** Windows & Walls (Woolsey) 500 1000 1500 2000 2500 3000 3500 0 HEAT LOSS [BTU/month] ■ ROOF WINDOWS WALLS **BASEMENT** 

### **Appliances Procedure**





### **Appliances Procedure**



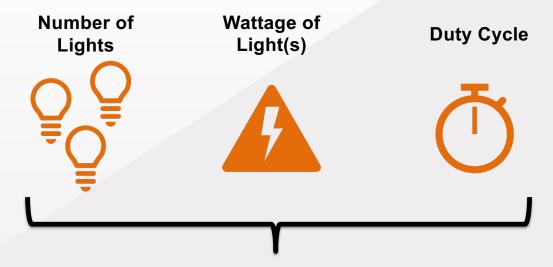
Range (Stovetop & Oven)



Water Heater



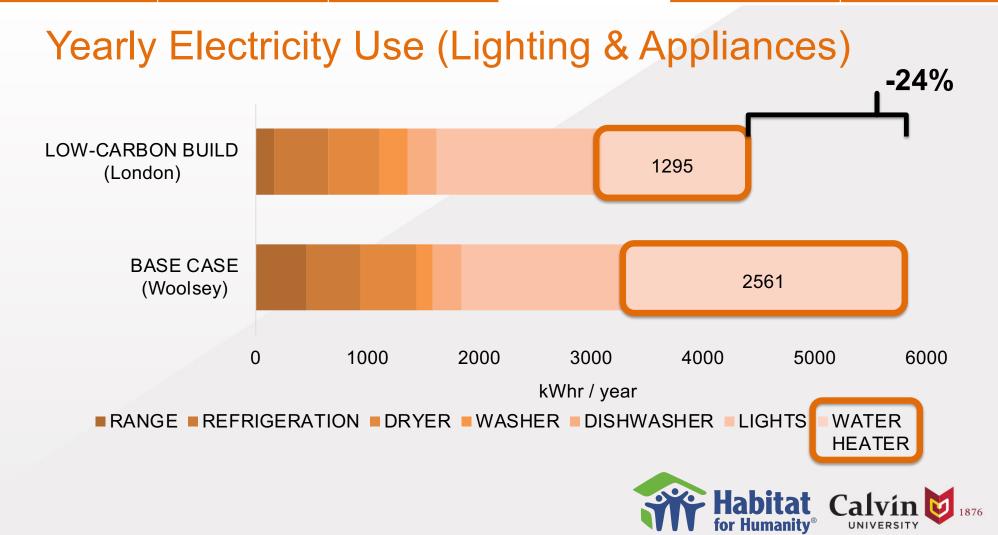
### Lighting Procedure



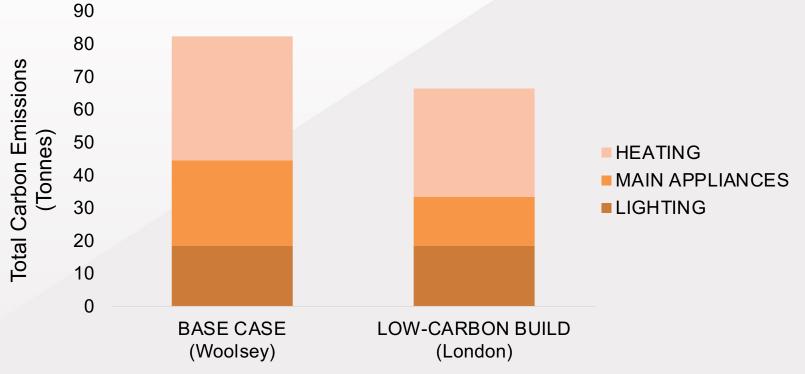
**Carbon Emissions from Lighting** 



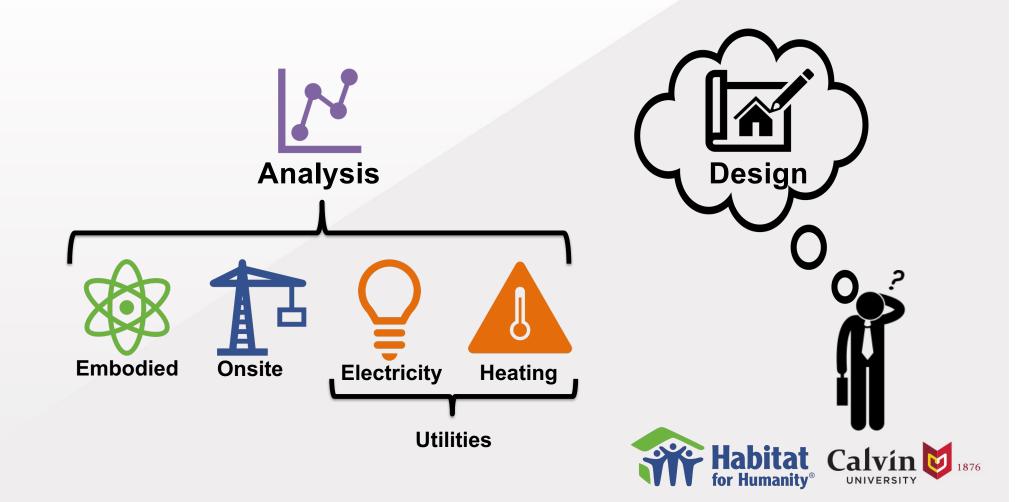




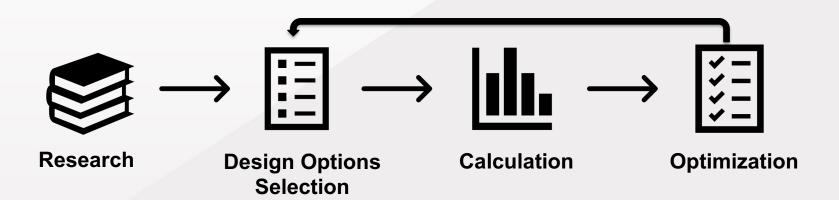
#### Carbon Emissions from Utilities







## Strategy

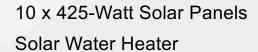




## **Design Options**



**Prefabricated Concrete Basement** 



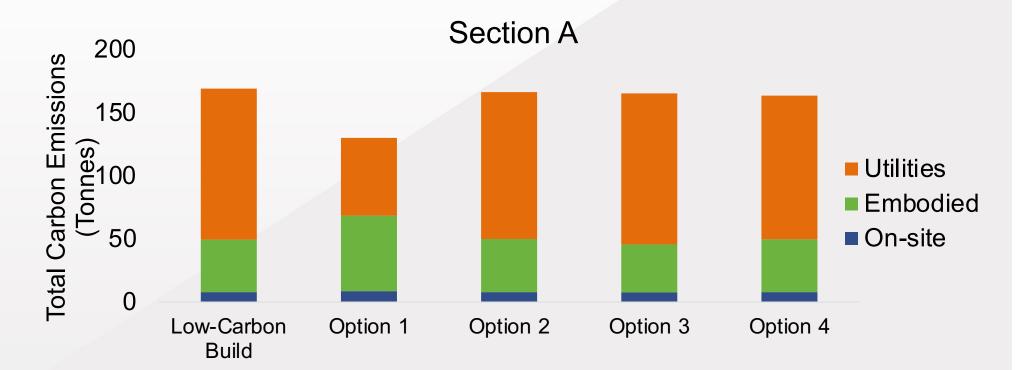
**Triple Pane Windows** Insulation – type and thickness (6x)





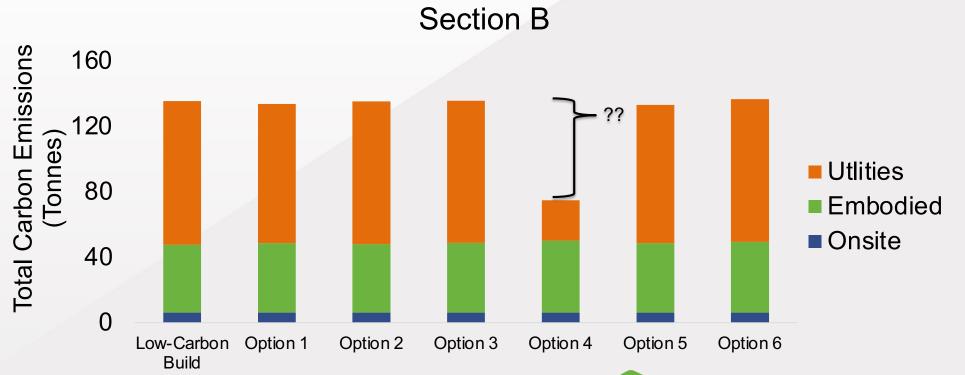


### Low Carbon Design Options





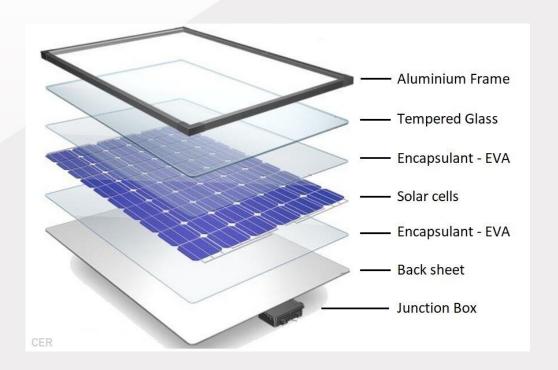
### Low Carbon Design Options





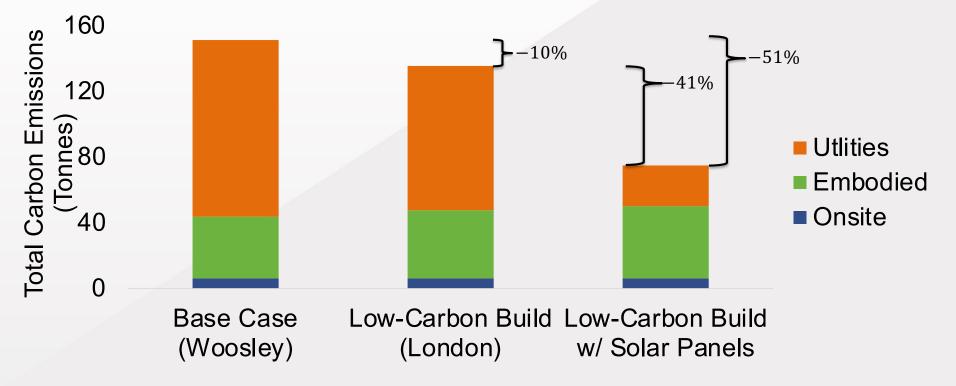
#### Solar Power Tradeoffs

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



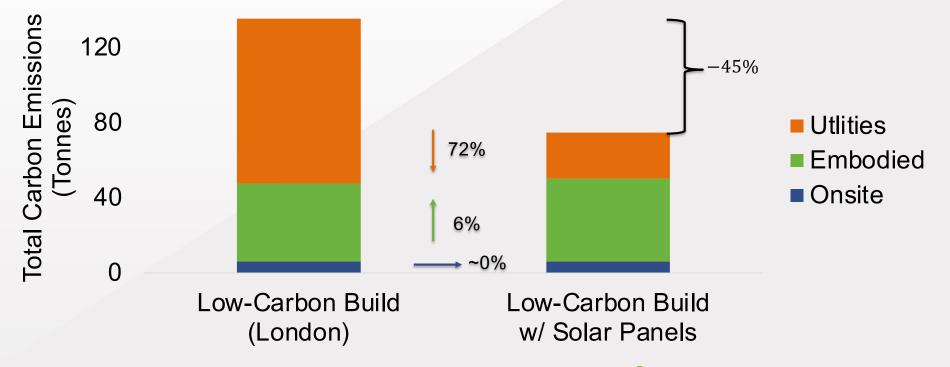


#### **Studied Home Comparisons**



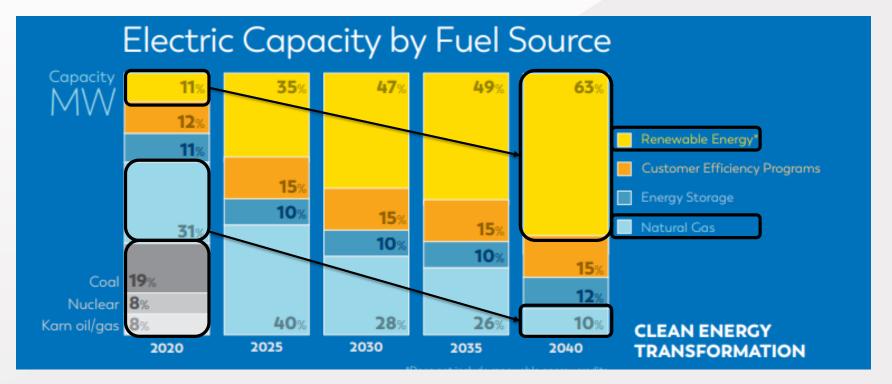


#### **Studied Home Comparisons**



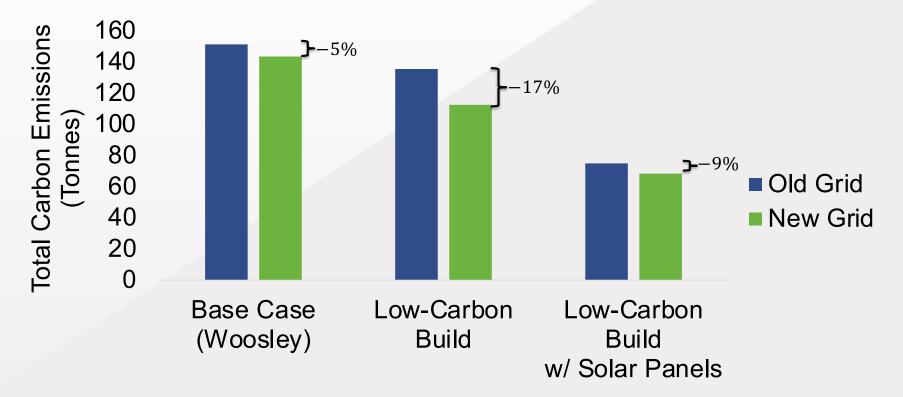


#### Consumers' Clean Energy Grid





### Clean Energy Grid Impacts





# Future Directions

# **Honorable Mentions**

- Financial Analysis
- Additional design options

-	<b>Prefab</b>	<b>Basement</b>	$\rightarrow$	<b>-4</b> %
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■ Solar Water Heater  $\rightarrow -6\%$ 

■ Triple Pane Windows  $\rightarrow -3\%$ 

■ Increased Insulation  $\rightarrow -3\%$ 



# 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** 



# Questions

