

# Dollars and Carbon:

## Effectiveness of Sustainable Construction Methods in the Roaring Fork Valley of Colorado

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From CORE – the Community Office for Resource Efficiency

## I - EXECUTIVE SUMMARY

Habitat for Humanity of the Roaring Fork Valley has built 19 homes in the Roaring Fork Valley region of Colorado since its inception in 2000. Since 2007, Habitat has attempted various sustainability upgrades to homes in an ad hoc manner based on volunteer interests or material donations. In an effort to be more methodical about their investment in sustainability, Habitat for Humanity in partnership with area architects, Confluence Architecture, received a design assistance grant from CORE (Community Office for Resource Efficiency) to study a “typical” Habitat home and find the most cost effective sustainable practices. The following report is the result of the research afforded by the CORE grant.

This study seeks to answer a subjective question: **How best can additional money and carbon be invested in the construction of an affordable home in the Roaring Fork Valley to minimize lifetime utility and carbon<sup>1</sup> costs?**

This question is investigated through the lens of a Habitat for Humanity home currently under construction in Carbondale, Colorado. While not changing the physical design of the home (shape, footprint, floor plan, windows, area etc.) 100+ home configurations are studied through LCA (life cycle analysis), energy modeling and construction cost estimates. The configurations focus on practical construction choices made every day such as wall assemblies, insulation levels, treatment of crawl spaces, attics and mechanical systems.

The study finds, unsurprisingly, that the most expensive home configuration to build saves the most carbon and has the lowest annual energy costs. The perfect mix between initial construction costs and carbon and energy savings is dependent on the values of the investor. In order to illustrate several successful investments, this report contains an in-depth analysis of 8 benchmark home configurations that illustrate practical construction combinations over a range of investment and performance levels. Following is a list of notable trends distilled from the data:

1. **The best way to reduce the carbon footprint of a home is to reduce operational energy consumption, even if it raises the initial construction carbon footprint.** The carbon footprint for materials, transportation, and construction of the home is exceeded by the carbon footprint of the annual energy usage in 3 years for a typical code home and 5 years for a high performing home. Construction carbon becomes important only as homes begin to reach net-zero and in some key carbon-rich construction materials.
2. **The largest factor in fuel consumption and construction cost is the mechanical system.** Avoid electric heating of any kind. Ducted furnace air systems are the lowest monetary cost path to efficient building heat. Hydronic systems provide

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<sup>1</sup> For the purposes of this report, carbon refers to Imperial tons CO2 equivalent, Specific components included in this metric are available in the Methods section (Section IV) of this report.

the best comfort and have an overall lower carbon footprint- with an added monetary investment.

3. **Avoid active cooling.** While air-conditioning use is increasing in the Roaring Fork Valley, energy modeling reveals it to be unnecessary for a well-designed and built home in our heating dominated climate. The cooling load is only 3% of the heating needed. Active cooling systems have the potential to use excessive electricity in an area where there is little need, especially if it is used in lieu of passive strategies (like appropriate clothing, opening windows at night, and proper shading of glazing).
4. **Insulation continues to be a cost effective way to increase building performance.** The type and location of insulation matter. This study found continuous exterior insulation to be more effective than added cavity insulation. SPF (Spray Polyurethane Foam) insulation<sup>2</sup> proved not to be as cost effective as other insulation types, going against an emerging trend for spray foam insulation in the Roaring Fork Valley. Beyond the cost and performance balance, insulation has the single largest impact on initial material carbon of any building component. The carbon footprint of like performing insulations types can vary 500-fold. The lowest carbon insulation option is blown cellulose while carbon intensive insulations are XPS<sup>3</sup> (Extruded Polystyrene) and SPF.
5. **Air Sealing is on par with insulation in its cost effectiveness in increasing building performance.** If careful air barrier control becomes a part of standard construction techniques the energy savings reward is significant relative to cost.
6. **Volume is a luxury.** Two homes that are identical on the exterior and have the same mechanical systems, windows, and shell construction can vary in energy performance by 5 - 15% due to the inclusion of vaulted interior spaces and conditioned crawl spaces. It is notable that this is one of the few areas where carbon and money are not at odds. More compact interior spaces are cheaper to build, require less initial construction carbon and are more efficient to run.
7. **Photovoltaics are becoming a key component to include in any home shell beyond the basic code minimum.** This came as a surprise to the study authors, questioning a rule of thumb where shell upgrades are better done prior to the addition of renewables. Due to continued price declines, PV is proving to be more economical than many shell upgrades such as high performing windows or super insulation.<sup>4</sup>
8. **Net-zero is not out of reach.** This study finds several home configurations that can be made net-zero in a construction price range (\$200-225/sf) that is in keeping with market rate construction and home sales costs in the Roaring Fork Valley. These homes use typical construction techniques and materials.

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<sup>2</sup> Closed Cell Spray polyurethane foam with HFC (hydrofluorocarbon) blowing agents

<sup>3</sup> Extruded Polystyrene, sometimes known as "blueboard". Not to be confused with EPS (Expanded polystyrene) which is typically white.

<sup>4</sup> Note: This is true only for the higher than construction costs in the Roaring Fork Valley region. Regions with lower labor/construction costs may still benefit from more labor intensive shell upgrades compared to the purchase of PV systems.

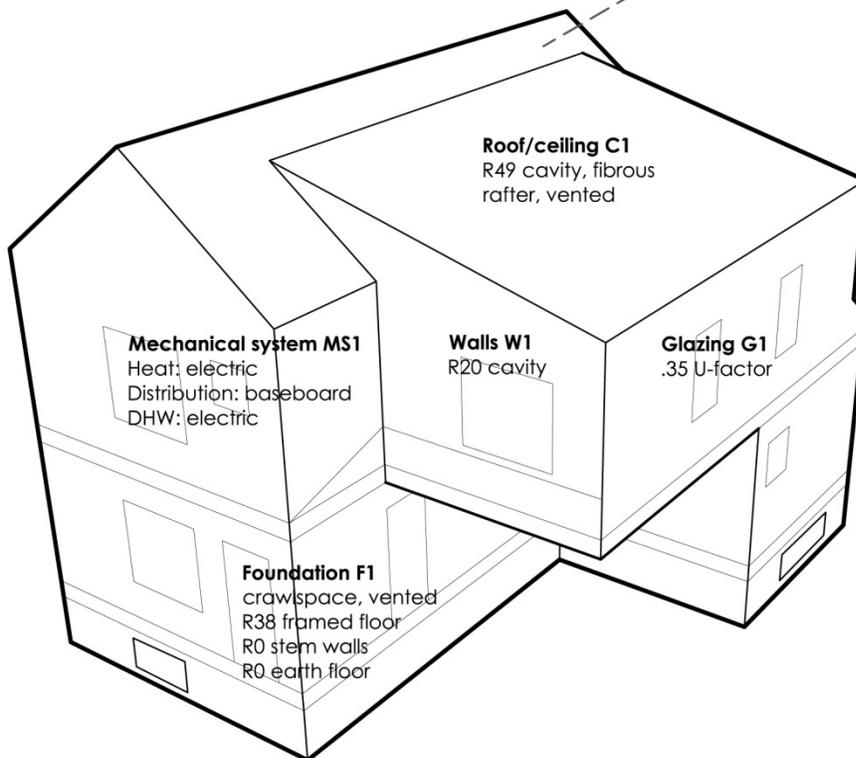
# A

## Home Configuration Baseline

Baseline configuration: this configuration is the starting point for comparisons. It is built to minimum code standards. It has the lowest construction cost and the highest annual energy costs.

Hypothetical Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 16.2 Kw PV solar array.

Increases construction cost to \$366,946 (\$207/sf) and increases construction carbon to 72.8 tons.

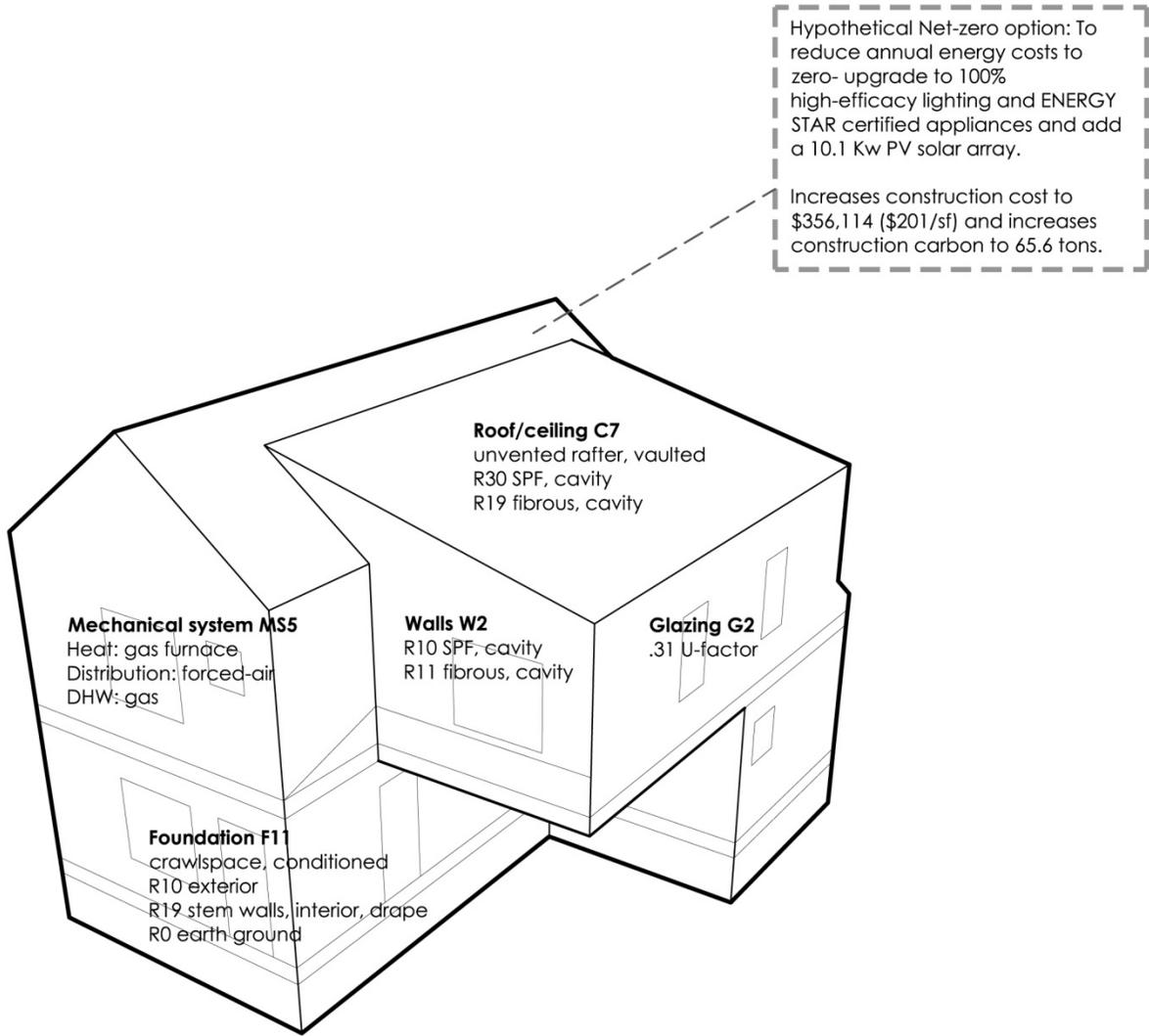


<b>Construction cost:</b>	<b>\$302,146 (\$171/sf)</b>
<b>Construction carbon:</b>	<b>32.2 tons</b>
<b>Annual energy cost:</b>	<b>\$3,141 &amp; 22.7 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>100</b>
<b>Tons of carbon after 60 years:</b>	<b>1411.7 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>D-</b>

For better performance - go to home configuration B

# B Home Configuration

This configuration utilizes a flash & batt technique



Hypothetical Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 10.1 Kw PV solar array.

Increases construction cost to \$356,114 (\$201/sf) and increases construction carbon to 65.6 tons.

<b>Construction cost:</b>	<b>\$314,214 (\$178/sf)</b>
<b>Construction carbon:</b>	<b>40.1 tons</b>
<b>Annual energy cost:</b>	<b>\$1,823 &amp; 11.1 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>69</b>
<b>Tons of carbon after 60 years:</b>	<b>763.0 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>C-</b>

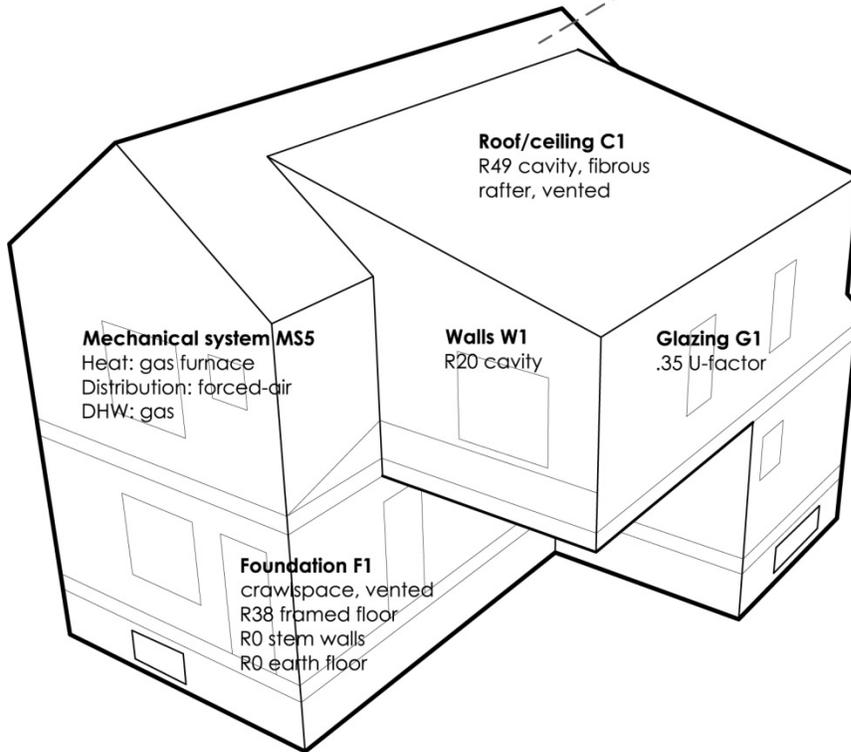
For better performance - go to home configuration C

# C Home Configuration

This configuration replaces electricity with gas for heating and water heating fuel.

Hypothetical Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 10.0 Kw PV solar array.

Increases construction cost to \$353,196 (\$200/sf) and increases construction carbon to 58.3 tons.



<b>Construction cost:</b>	<b>\$311,696 (\$176/sf)</b>
<b>Construction carbon:</b>	<b>33.1 tons</b>
<b>Annual energy cost:</b>	<b>\$1,780 &amp; 10.9 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>67</b>
<b>Tons of carbon after 60 years:</b>	<b>704.6 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>C-</b>

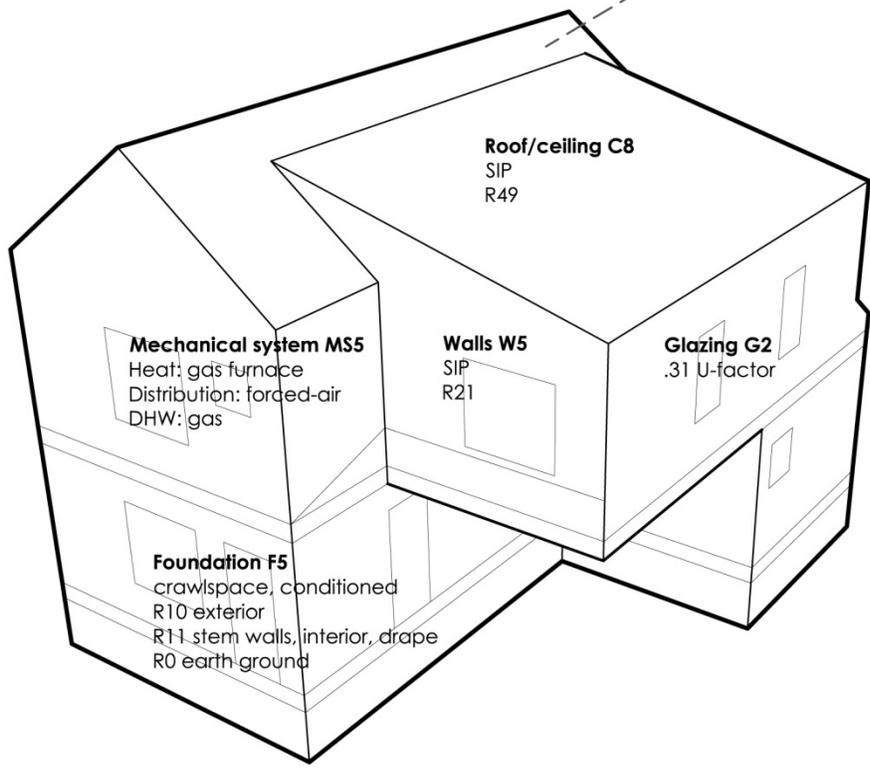
For better performance - go to home configuration D

# D Home Configuration

This configuration upgrades the envelope to SIPs for the roof and walls.

Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 9.9 Kw PV solar array.

Increases construction cost to \$374,681 (\$212/sf) and increases construction carbon to 59.8 tons.



<b>Construction cost:</b>	<b>\$333,581 (\$188/sf)</b>
<b>Construction carbon:</b>	<b>35.0 tons</b>
<b>Annual energy cost:</b>	<b>\$1,773 &amp; 10.8 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>67</b>
<b>Tons of carbon after 60 years:</b>	<b>699.3 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>C-</b>

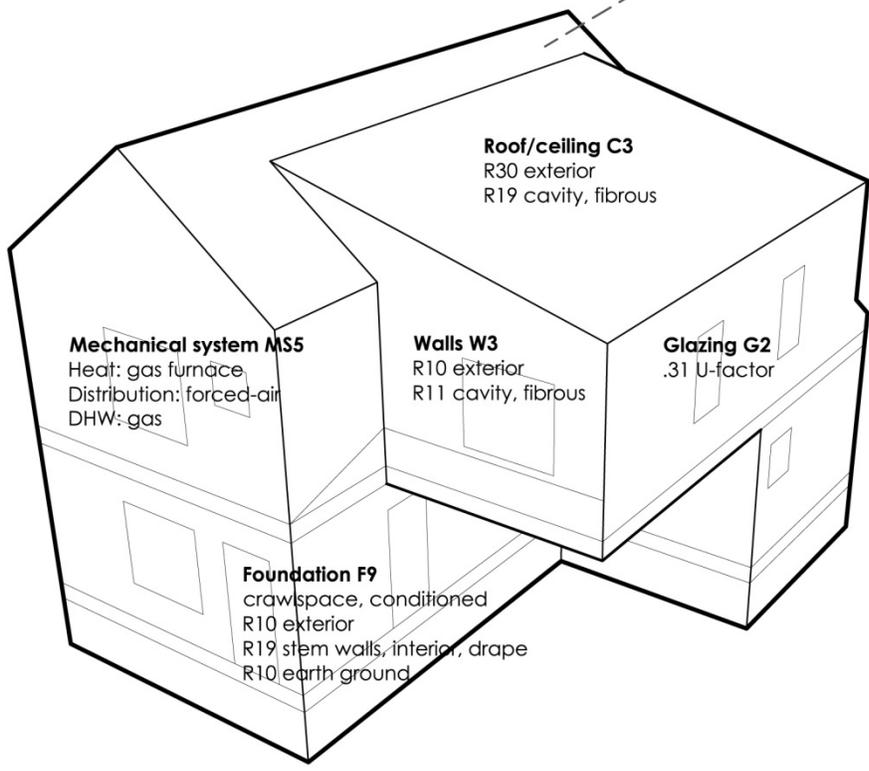
For better performance - go to home configuration E

# E Home Configuration

This configuration uses exterior insulation.

Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 9.7 Kw PV solar array.

Increases construction cost to \$372,670 (\$211/sf) and increases construction carbon to 58.5 tons.



<b>Construction cost:</b>	<b>\$332,370 (\$188/sf)</b>
<b>Construction carbon:</b>	<b>34.0 tons</b>
<b>Annual energy cost:</b>	<b>\$1,740 &amp; 10.5 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>64</b>
<b>Tons of carbon after 60 years:</b>	<b>680.5 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>C</b>

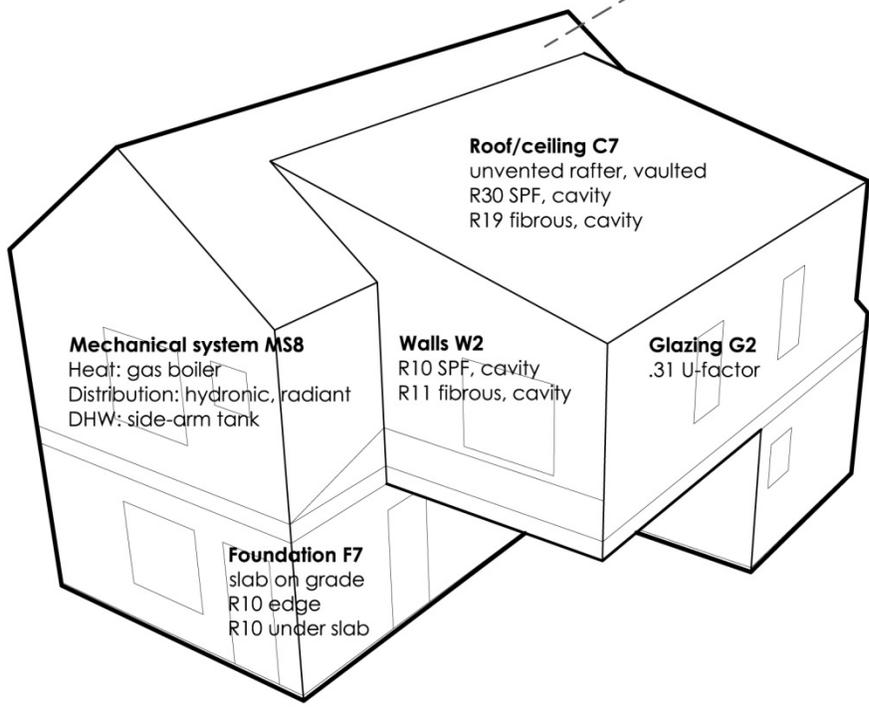
For better performance - go to home configuration F

# F Home Configuration

Hydronic distribution and a gas-fired boiler with side-arm water heating. This configuration has flash & batt insulation.

Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 8.8 Kw PV solar array.

Increases construction cost to \$355,303 (\$201/sf) and increases construction carbon to 63.1 tons.



<b>Construction cost:</b>	<b>\$318,603 (\$201/sf)</b>
<b>Construction carbon:</b>	<b>40.9 tons</b>
<b>Annual energy cost:</b>	<b>\$1,541 &amp; 9.7 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>62</b>
<b>Tons of carbon after 60 years:</b>	<b>659.9 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>B</b>

For better performance - go to home configuration G

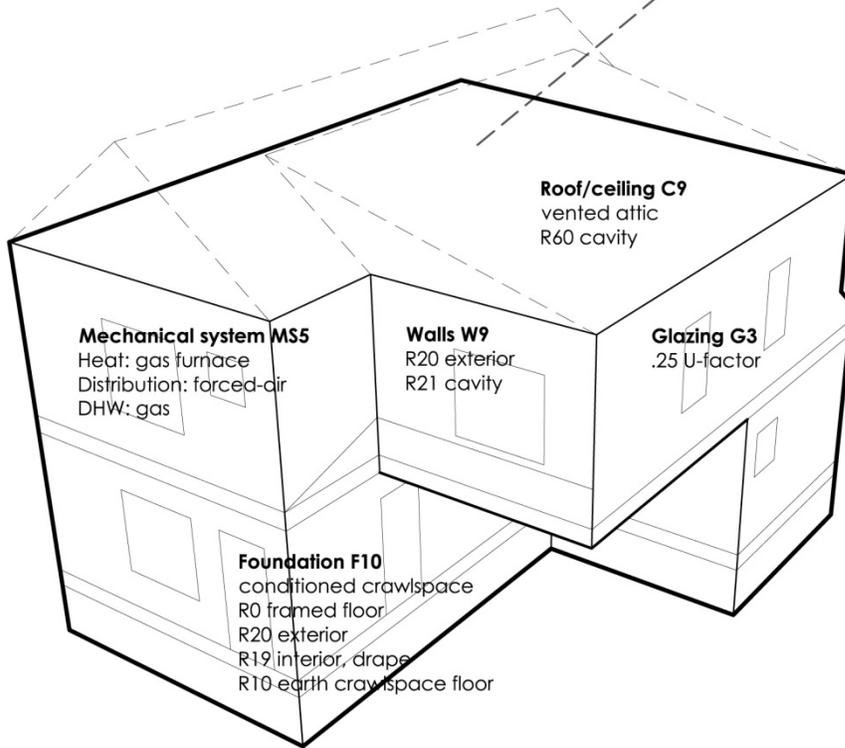


# Home Configuration

This configuration is heavily insulated.

Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 8.0 Kw PV solar array.

Increases construction cost to \$366,512 (\$207/sf) and increases construction carbon to 54.0 tons.

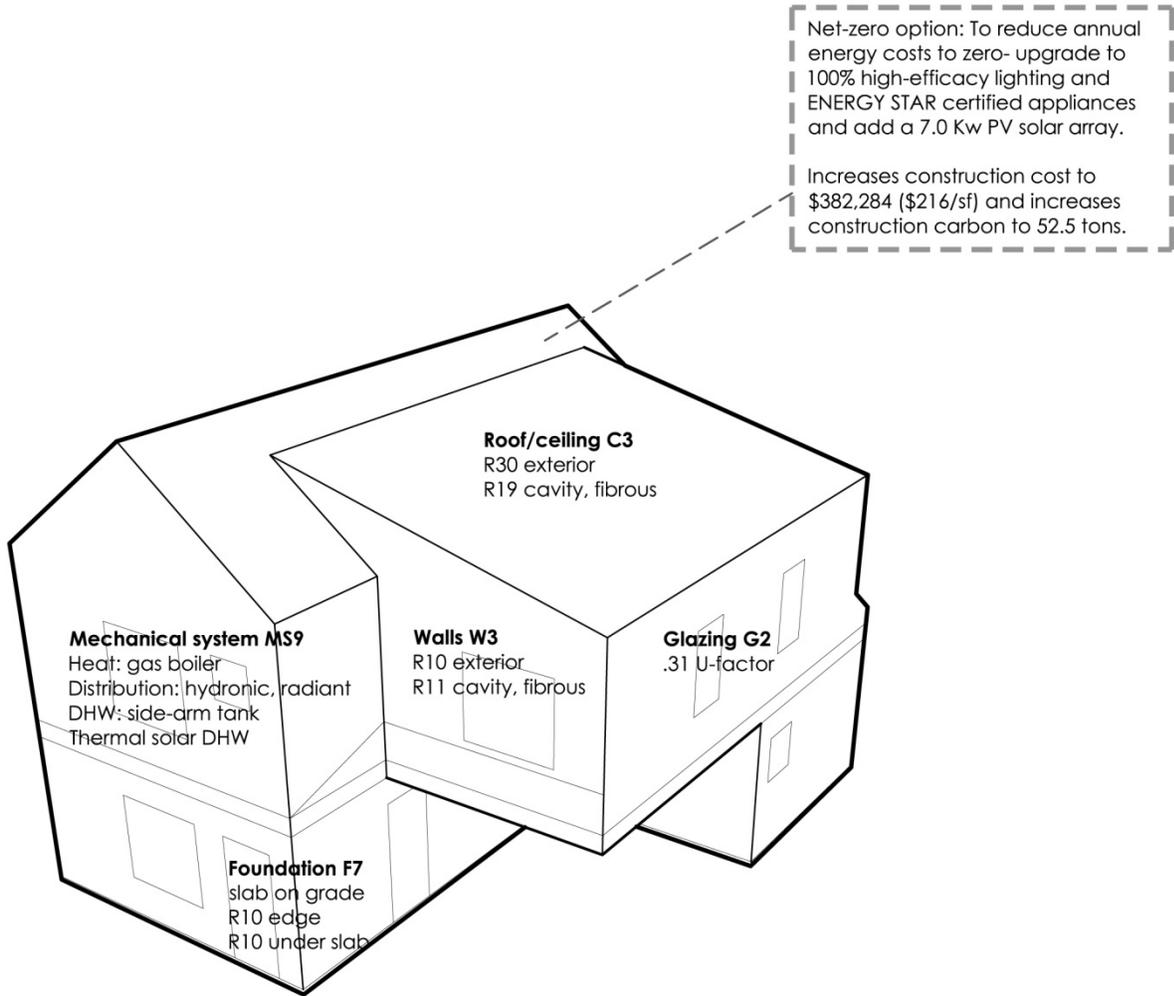


<b>Construction cost:</b>	<b>\$333,012 (\$188/sf)</b>
<b>Construction carbon:</b>	<b>33.8 tons</b>
<b>Annual energy cost:</b>	<b>\$1,506 &amp; 9.2 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>47</b>
<b>Tons of carbon after 60 years:</b>	<b>608.7 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>A-</b>

For better performance - go to home configuration H

# H Home Configuration

This configuration is exterior insulation.



<b>Construction cost:</b>	<b>\$352,784 (\$199/sf)</b>
<b>Construction carbon:</b>	<b>34.8 tons</b>
<b>Annual energy cost:</b>	<b>\$1,359 &amp; 8.3 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>50</b>
<b>Tons of carbon after 60 years:</b>	<b>549.9 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>B</b>

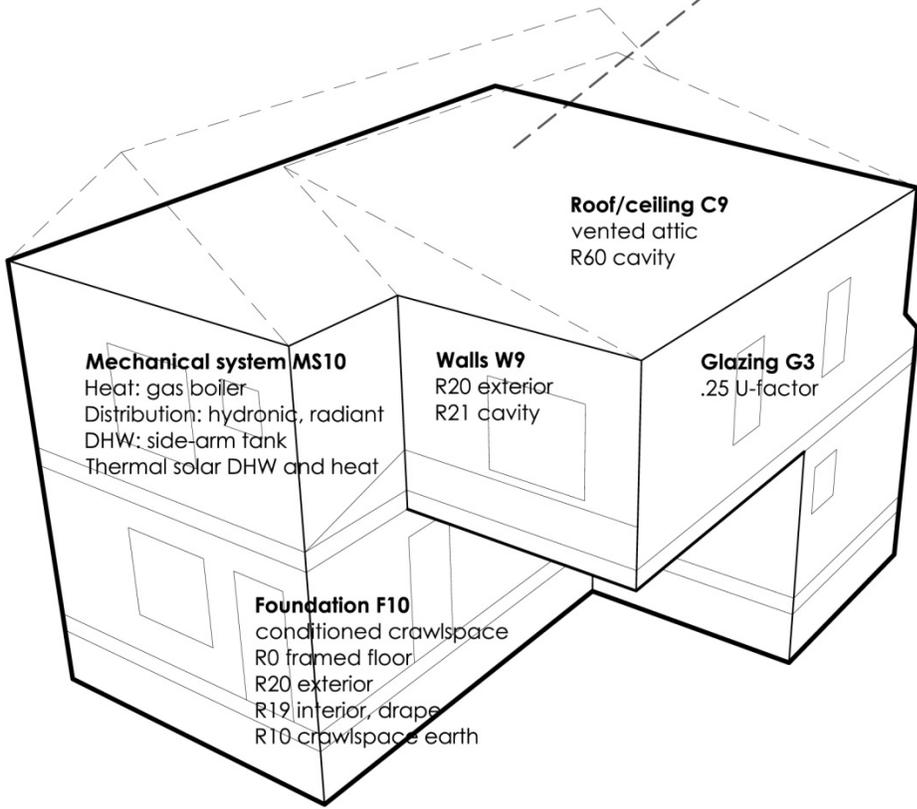
For better performance - go to home configuration I

# I Home Configuration

This configuration is heavily insulated.

Net-zero option: To reduce annual energy costs to zero- upgrade to 100% high-efficacy lighting and ENERGY STAR certified appliances and add a 5.0 Kw PV solar array.

Increases construction cost to \$393,180 (\$222/sf) and increases construction carbon to 48.5 tons.



<b>Construction cost:</b>	<b>\$371,680 (\$210/sf)</b>
<b>Construction carbon:</b>	<b>35.8 tons</b>
<b>Annual energy cost:</b>	<b>\$1,134 &amp; 6.9 tons of CO2</b>
<b>Home Energy Rating Score:</b>	<b>30</b>
<b>Tons of carbon after 60 years:</b>	<b>472.6 tons</b>
<b>Quality, Comfort &amp; Durability:</b>	<b>A</b>