# Appendix L.

## A.Carbon Emission Analysis

One of our central goals for this project is to provide a solution that drastically reduces the global warming footprint/potential (or GWP) for buildings of this typology. The team recognizes the immediacy of the need to reduce emissions and therefore is interested in a much shorter time frame for analyzing the total GWP of the project, than is typically studied in a total life cycle GWP analysis which could encompass 100 years. The chart below from AIA2030 indicates that for a typical high performance new building, the impact of the embodied GWP of the materials is much greater in the first 10-30 years, which is the timeframe we are interested in drastically reducing now, so that we can truly mitigate our climate issues.

**CARBON EMISSIONS FOR NEW CONSTRUCTION BUILDING**

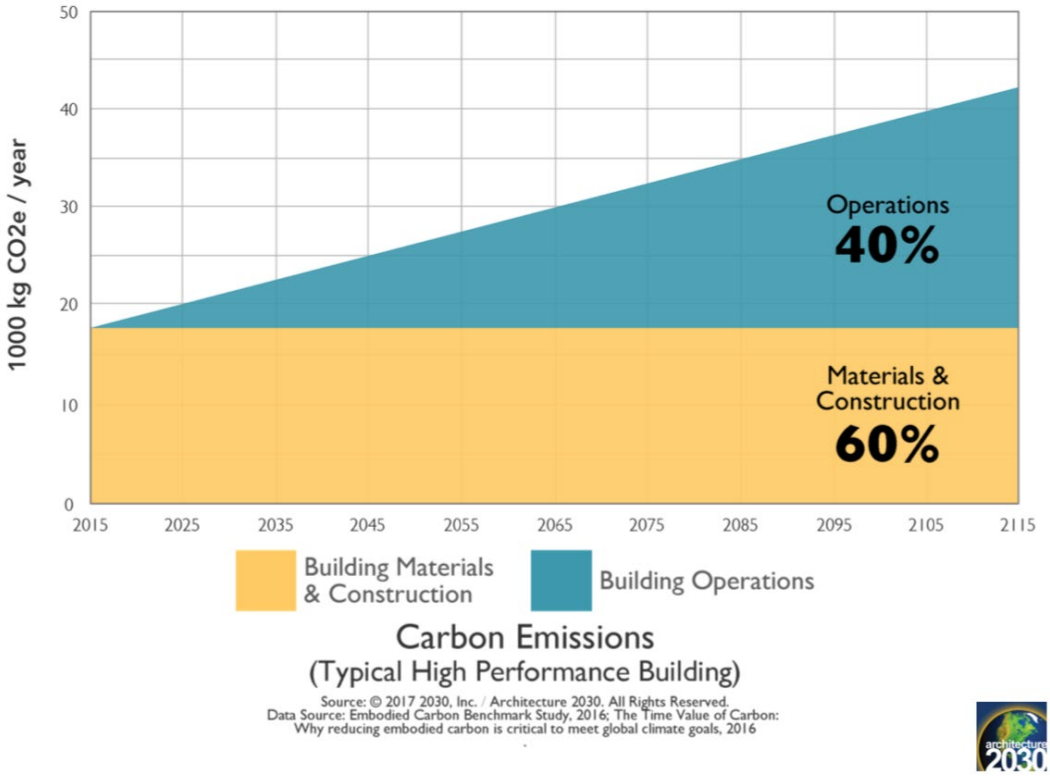


**FIGURE 1: CARBON EMISSIONS FOR NEW CONSTRUCTION BUILDING**

The chart shows a cumulative tally of the GWP of a typical high performance building.

Therefore the team recognizes that the physical materials we are using in the renovation process, have a significant impact on the total GWP performance of the building. Performing a complete greenhouse gas life cycle analysis however has been determined to be too time consuming at this stage but an analysis has been done on the use of mineral wool (MW) or Expanded Polystyrene (EPS) as insulation materials for the exterior walls and roof. This analysis was done while considering insulating exterior walls from the exterior and refers to the scope presented in the Schematic Design submission to NYSERDA in December 2018.

Below are the results of this analysis for one building:

1. Total embodied carbon in insulation for this project[1]:
   MW: 26,634 lbs CO2eq
   EPS: 42,024 lbs CO2eq

2. Carbon emission reductions from the entire project scope:
   322,717 lbs CO2eq/yr

For this specific analysis, it is assumed that community solar subscriptions are not used so that they do not "artificially" increase carbon emission reductions.

From an embodied carbon perspective only, it appears that EPS or MW could be used on this project, but that MW should be preferred if possible. In addition, MW has other benefits over foam insulation such as fire resistance.

Note: The embodied carbon of XPS is about 49 times that of EPS. Using XPS for insulation may then not make sense from a carbon life cycle analysis. If XPS had been used to over-clad this building then the global warming potential savings from the reduced operational energy use would not start to be realized for this project until at least 6 years after the renovation. This calculation only takes the insulation into account and doesn't include any other materials or processes that would be used.

A broader analysis has also been performed by the team and takes into account the global warming potential associated to the embodied carbon of insulation materials (mineral wool), to the refrigerant leaks of the VRF system and to the energy use of the building over the course of 30 years.

Figure 2 compares the global warming of two scenarios, retrofitting the buildings using the "Most efficient" scope described in the Final Report or not doing any energy efficiency upgrade.

[1] This assumes embodied carbon of 48.85 kg CO2eq/m3 for MW and 77.08 kg CO2eq/m3 for EPS with materials having an R-4 per inch insulation value.

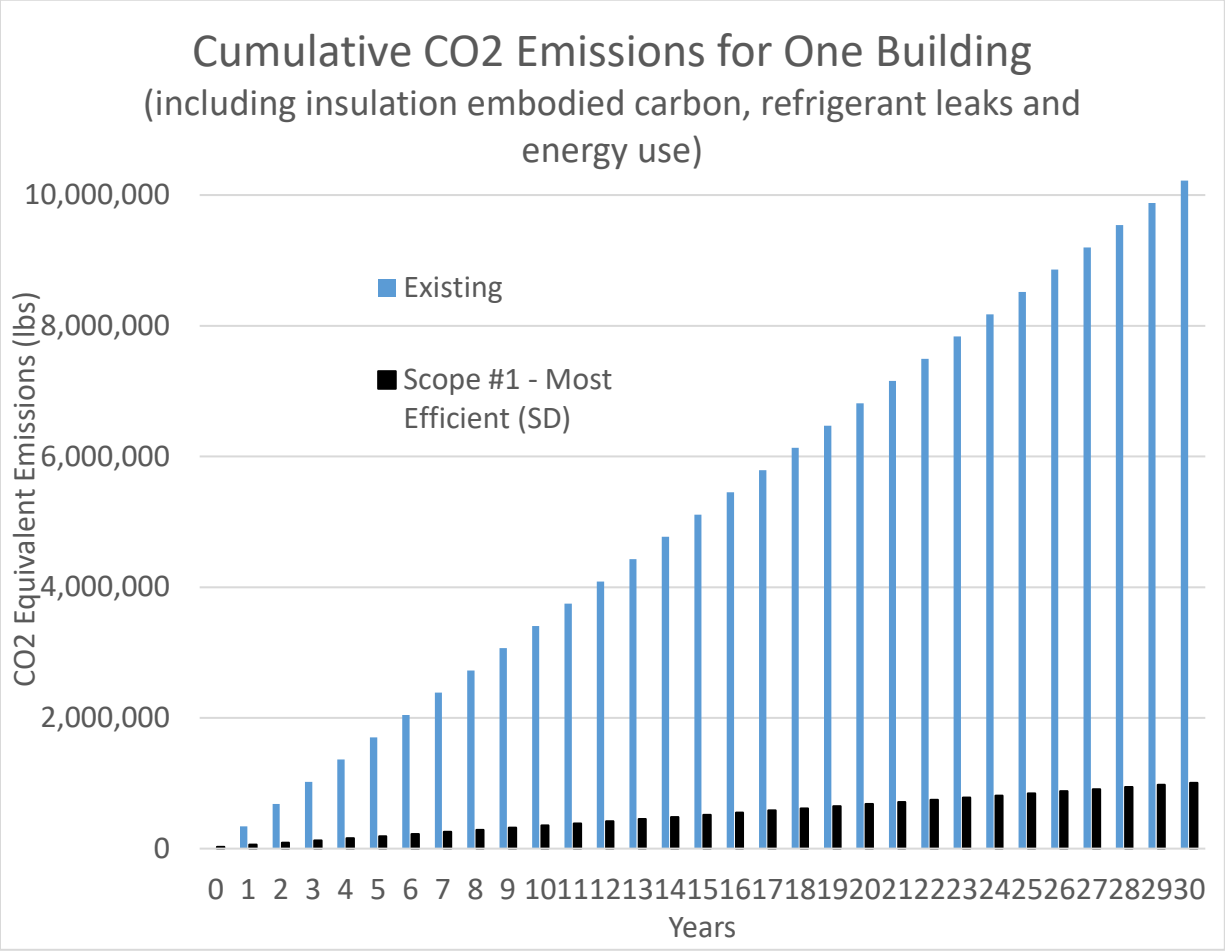


**FIGURE 2: CUMULATIVE CO2 EQUIVALENT EMISSIONS FOR DEEP RETROFIT SCOPE**

While not being as comprehensive as a full carbon life cycle analysis, the results shown on Figure 2 suggest that the carbon emission reduction related to implementing a deep retrofit scope is significant.

## B.Global Warming Potential Analysis for Refrigerants

A preliminary analysis performed by the team aimed at determining the following:

1. Could the global warming potential related to refrigerant leaks significantly offset carbon emission reductions?
2. Would the HVAC option selected among our four preliminary options have a significant impact on global warming potential?

The following chart shows the global warming potential related to refrigerant leaks assuming that 100% of the refrigerant contained in the heating and cooling system including piping, would ultimately leak every 12 years. It also gives an estimate of how much carbon emission reduction would be achieved over the course of 12 years from energy savings solely, assuming 80% carbon emission reduction (conservative assumption at a preliminary stage).

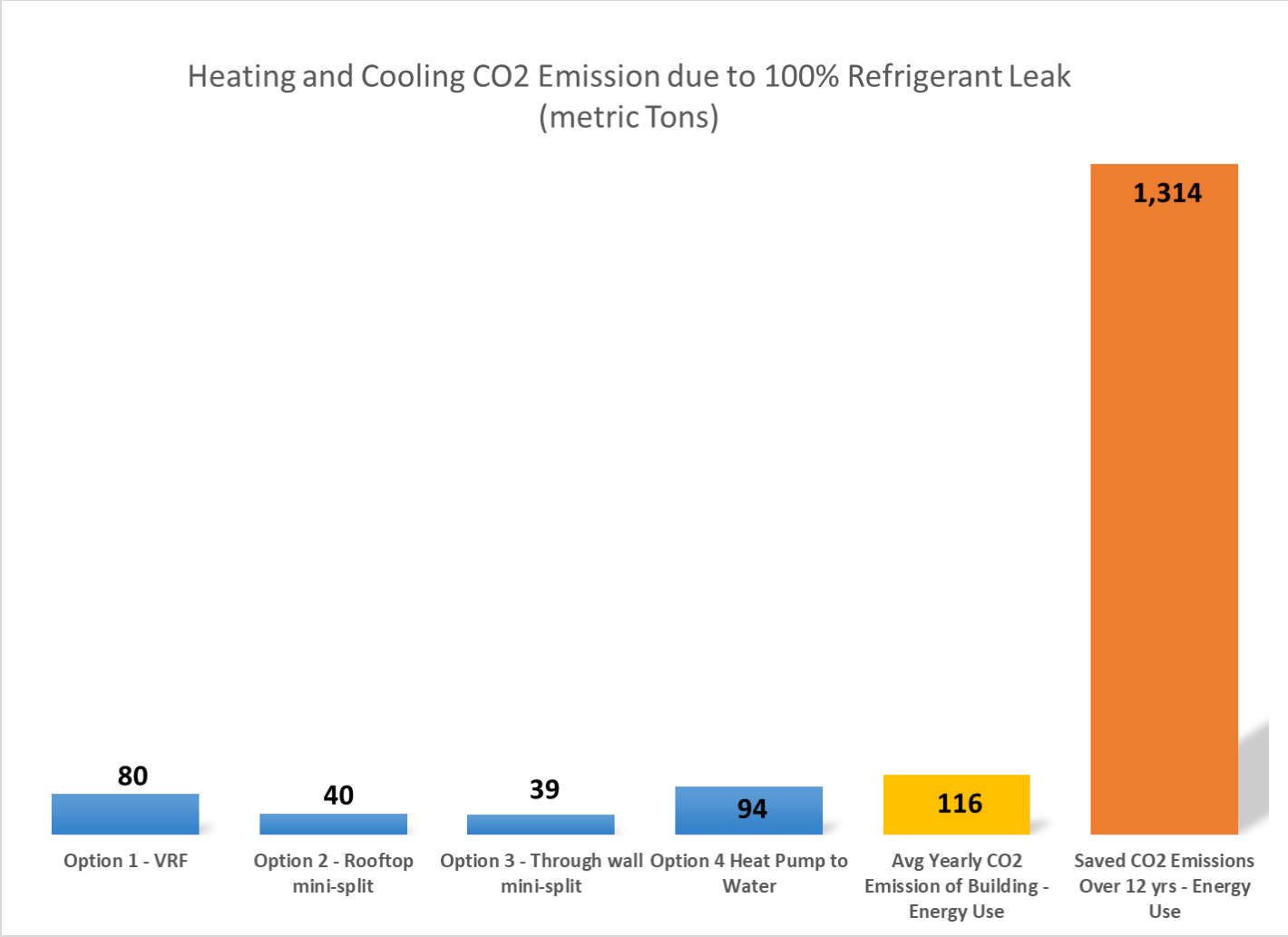


**FIGURE 3: CO2 EMISSIONS FOR DIFFERENT HVAC OPTIONS VS SAVED CO2 EMISSIONS FROM ENERGY SAVINGS (300 E 162)**

The refrigerant used in the heat pump systems considered here is R-410A and its GWP is 1725[2].

Based on the results shown above, the HVAC system does not significantly offset the carbon emission reductions achieved through energy savings.

Although there is a significant relative difference in equivalent carbon emissions between HVAC options, choosing one option over another does not seem necessary as the carbon emissions related to refrigerant leaks are very low compared to the carbon emissions related to energy savings anyway.

## C.Comparison of Insulation Materials

Please refer to Insulation Comparison document.

[2] Based on this resource: https://www.engineeringtoolbox.com/refrigerants-properties-d_145.html

## D.Energy Modeling Schedules

See below:

| | | | | Source |
|---|---|---|---|---|
| Apartments | | | | |
| Type | Hours Week Day | Hours Saturday | Hours Sunday | |
| Lighting | 4 | 4 | 4 | Based on energy model true up agaist actual electric data. |
| Equipment | 5.8 | 5.8 | 5.8 | Energy Star Multifamily High Rise Program Protocol |
| Occupancy | 15.7 | 19.5 | 19.5 | Energy Star Multifamily High Rise Program Protocol |

| Mechanical | | | | |
|---|---|---|---|---|
| Type | Hours Week Day | Hours Saturday | Hours Sunday | |
| Lighting | 4 | 4 | 4 | Energy Star Multifamily High Rise Program Protocol |
| Equipment | 9 | 9 | 9 | Energy Star Multifamily High Rise Program Protocol |
| Occupancy | 4.0 | 4 | 4 | Energy Star Multifamily High Rise Program Protocol |

| Corridor | | | | |
|---|---|---|---|---|
| Type | Hours Week Day | Hours Saturday | Hours Sunday | |
| Lighting | 24 | 24 | 24 | Energy Star Multifamily High Rise Program Protocol |
| Equipment | 9 | 9 | 9 | Energy Star Multifamily High Rise Program Protocol |
| Occupancy | 12.9 | 12.85 | 12.85 | Energy Star Multifamily High Rise Program Protocol |

| Stairs | | | | |
|---|---|---|---|---|
| Type | Hours Week Day | Hours Saturday | Hours Sunday | |
| Lighting | 24 | 24 | 24 | Energy Star Multifamily High Rise Program Protocol |
| Equipment | 9 | 9 | 9 | Energy Star Multifamily High Rise Program Protocol |
| Occupancy | 12.9 | 12.85 | 12.85 | Energy Star Multifamily High Rise Program Protocol |

| Lobby | | | | |
|---|---|---|---|---|
| Type | Hours Week Day | Hours Saturday | Hours Sunday | |
| Lighting | 24 | 24 | 24 | Energy Star Multifamily High Rise Program Protocol |
| Equipment | 9 | 9 | 9 | Energy Star Multifamily High Rise Program Protocol |
| Occupancy | 12.9 | 12.85 | 12.85 | Energy Star Multifamily High Rise Program Protocol |

| Laundry Equipment | | | | |
|---|---|---|---|---|
| Type | kWh/load | Loads/year | | |
| Washer | 135 | | | kWh/year: NYSERDA research and integrative design process (IDP) coach. |
| Dryer | 150 | | | kWh/year: NYSERDA research and integrative design process (IDP) coach. |

## E.Parametric Analysis

| Item | Bundle 1 Option A | Bundle 1 Option B | % additional energy savings | % additional Cost savings | Additional $ Savings | Bundle 1 Option C | % additional energy savings | % additional Cost savings | Additional $ Savings | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Exterior insulation of 1st floor street facade | 6" | 6" + interior insulation | 0.03% | 0.03% | $ 5 | No ext insulation +int insulation | -0.21% | -0.21% | $ (37) | Interior insulation not required in addition to ext insulation.<br>Interior insulation instead of ext may be okay. |
| Exterior insulation of the exterior walls -other walls | all the way down past grade (sidewalk and courtyard) on all facades 3' | down to grade | -3.6% | -3.6% | $ (643) | | | | | 3' past grade should be selected |
| Roof Insulation | R-50+ Stone Wool 4" | R-50 + nothing | -0.11% | -0.11% | $ (20) | R-50 + Stone wool 8" | 0.09% | 0.09% | $ 16 | Adding insulation on deck has no impact => remove deck insulation |
| Windows | Tilt & Turn / Casement (tripple glazed) U-0.203 SHGC 0.206 | Tilt & Turn / Casement (double glazed) U-0.277 SHGC 0.258 | -0.9% | -0.9% | $ (166) | | | | | Triple pane adds significant energy savings => keep |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Slab Insulation | rigid stone wool: R16 (4") over existing slab + floated floor | No slab insulation | -2.2% | -2.2% | $ (397) | | | | | Slab insulation adds significant energy savings => keep if possible. |
| Heating & Cooling | VRF | Mini Splits | -3.1% | -3.1% | $ (547) | Air to water Heat Pump | -5.0% | -5.0% | $ (892) | VRF is significantly more efficient than mini-splits and heat pump to water => choose VRF |
| DHW Heating | HP Water Heater | Electric Resistance | -37.9% | -37.9% | $(6,753) | | | | | Heat pump water heater has a VERY significant impact on energy savings => use heat pumps. |
| Washers and Dryers | 1 laundry room for 2 buildings | in unit | | | $ - | | | | | Option already selected (central laundry) |
| Grey water heat recovery | Grey water heat recovery | No recovery | -7.0% | -7.0% | $(1,250) | | | | | Grey water adds significant energy savings => keep. |
| Shades | No shades | Horiz and Vertical Shades | 0.00% | 0.00% | $ - | horizontal shades | 0.1% | 0.1% | $12 | b. Heating penalty outweighting cooling savings => include? |
| Metal Girts | Thermally broken Girts | Metal Girts | -0.14% | -0.14% | $ (25) | | | | | |