Estimating Operational Energy Saving and Carbon Footprint Reduction Potential of BamCore Prime Wall System for One Typical Housing Design in the United States of America

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BamCore
5900 Pruitt Avenue, Suite 110
Windsor, CA 95492

Prepared by

Greentech Knowledge Solutions Pvt. Ltd.

Greentech Knowledge Solutions Pvt. Ltd. (GKSPL)
342, Abhiyan Apartments, Plot 15, Sector 12, Dwarka
New Delhi -110078 (India)

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1. Introduction

1.1 Background

BamCore has developed a bamboo-based Prime Wall system which is stud-less, stronger, greener, thermally superior, healthier, safer, quieter, and more quickly installed than any other conventional framing solution available today. Having buildings constructed in the USA using this Prime Wall System, BamCore is planning for a comparative study of several wall assemblies commonly used in United States of America using carbon footprint (both embodied and operating carbon) as an assessment parameter.

Greentech Knowledge Solutions Private Limited is a premier Indian consulting and research company in the field of energy-efficient and low-carbon buildings. GKSPL has more than 15 years of experience in this area and is known for its insightful research, which among other achievements, has resulted in the development of the first residential building energy code in India. GKSPL is particularly known for its expertise in building energy simulation, measurement of building energy performance and walling materials.

In September 2022, GKSPL assisted BamCore in carrying out a pilot study focused on estimating the operational energy savings (space cooling and space heating) and reduction in carbon footprint by using the BamCore Prime Wall system as compared to typical walling construction used in India. The BamCore team found the study very useful as it adds to their credibility and are commissioning a follow-up study to quantify the Bamcore Prime Wall system performance in the climate of Dallas, Texas, and compare it with the predominant building construction used in USA. BamCore and GKSPL have agreed that the building configuration used for the pilot study in September 2022 can also be used for this study.

1.2 Objective

The scope of this study is to do an estimation of operational energy savings (space heating and space cooling) and reduction in embodied carbon by using BamCore's Prime Wall system as compared to three other predominant types of building materials used in US construction. The study targets residential low-rise buildings constructed on individual plots and occupied by urban upper middle-class families. It is assumed that the house is fully air-conditioned.

2. Selection of typical housing plan and location

2.1 Housing plan

The building design used in the previous study (September 2022), shall be used in this study. However, one floor is added, keeping the floor plan same. The building is a 5-storey (Ground + 4 floors) residential building of total built-up area of around 550 m^2, constructed on a plot area of 200 m^2 plot area. The building design is a representative housing type in urban areas, particularly amongst the families belonging to upper middle class. Typically, such a house will be occupied by 2-3 families.

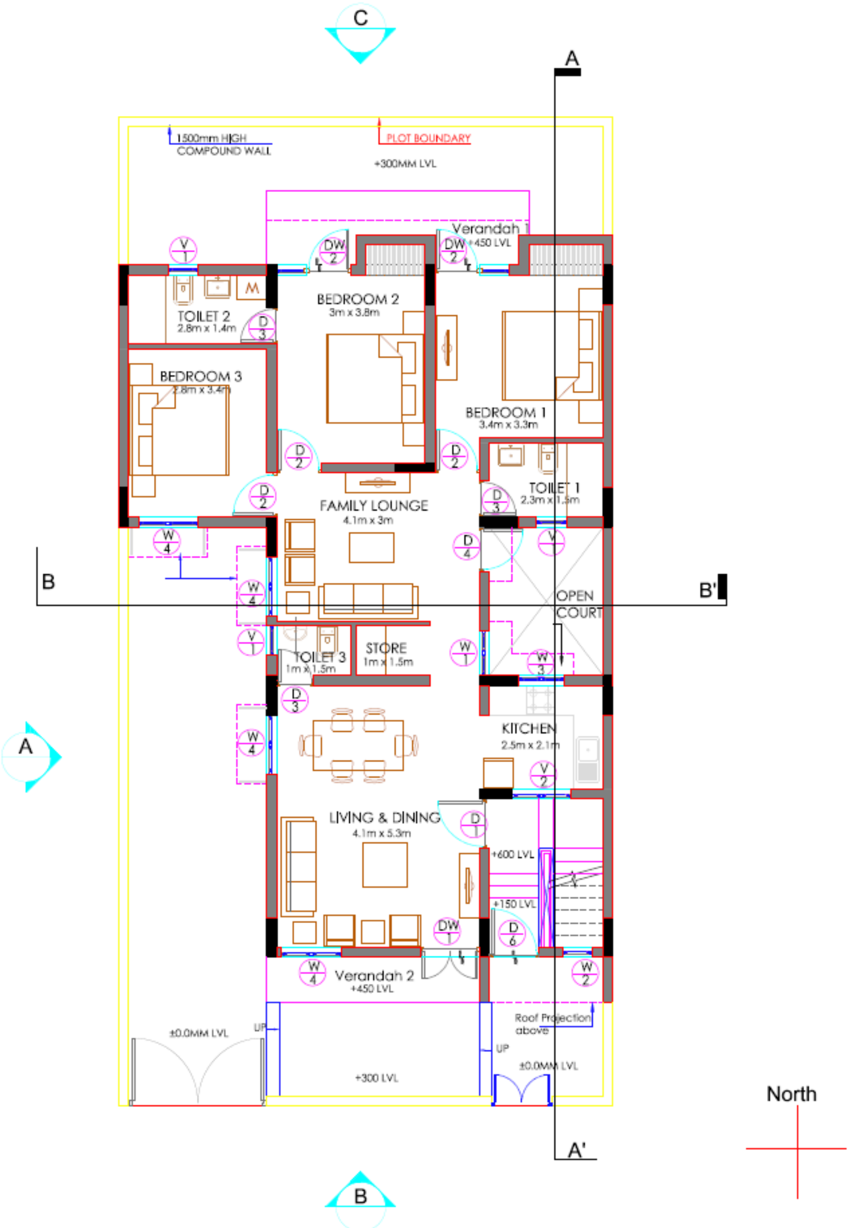


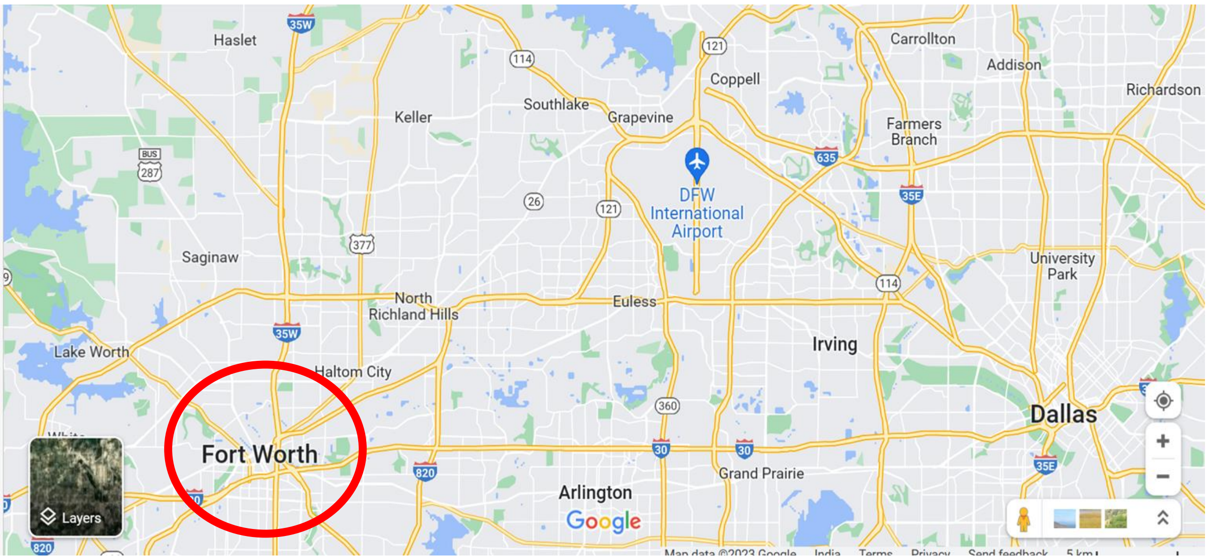
Figure 1: Floor plan of the house

The floor plan for all the floors remains the same.

2.2 Location

The simulation study will be conducted for Dallas, Texas - located in the Southwest region of the United States. Dallas is Climate Zone 3, Moisture Regime A, BA Zone Hot-Humid.

The weather data file of Fort Worth is considered for the simulation.



3. Compilation of building energy simulation inputs

The building energy simulation will be carried out using the EnergyPlus software[1] (DesignBuilder interface[2]).

The key inputs for the energy simulation are listed below. All the inputs were mutually agreed between BamCore and GKSPL team. These inputs include:

- Building geometry and zoning
- Wall, window, roof construction details and technical specification
- Occupant, lighting and equipment loads and their schedule
- Heating/cooling system specification and set point
- Use of natural ventilation

3.1 Building geometry and zoning

The building geometry is prepared in the simulation model as per the architectural drawings. However, simplified zoning is done to merge the area which have same usage.

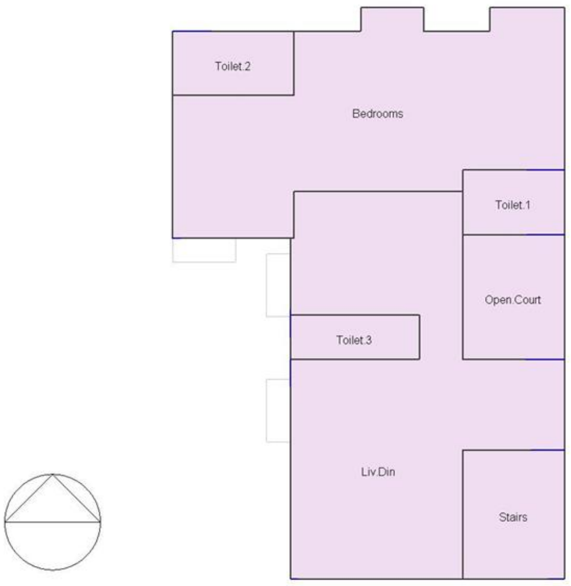


Figure 2: Simplified zoning based on space usage

Window-to-wall ratio and shading is added as per the architectural drawing. Below is the 3D image of the simulation model.

[1] EnergyPlus software developed with support from the US DoE is considered one of the best software's for building energy simulation (https://www.energy.gov/eere/buildings/downloads/energyplus-0)
[2] DesignBuilder is a simulation software based EnergyPlus simulation engine, with an easy-to-use graphical user interface (GUI) (https://designbuilder.co.uk/)

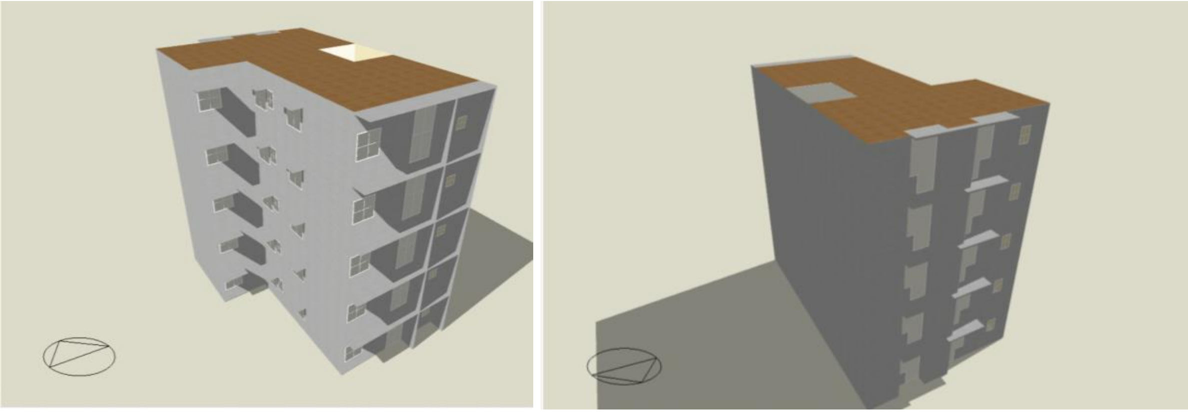


Figure 3: 3D simulation model prepared in DesignBuilder

3.2 Wall, window, roof construction details and technical specification

The study compares BamCore Prime wall construction with the business-as-usual construction in the USA. For this comparative study, four cases have been prepared with different set building envelope parameters as shown below.

Table 1: Building energy simulation inputs for envelope inputs

Parameter	Case 1: BamCore Prime Wall	Case 2. Wood with rigid foam	Case 3. Wood without rigid foam	Case 4. Steel Stud infill
Exterior Wall Construction	BamCore Prime Wall	Wood stud 25% framing factor with rigid foam	Wood stud 25% framing factor without rigid foam	Steel Stud infill, with batt insulation and exterior rigid foam insulation
Exterior Wall U-value	0.23 $W/m^2.K$ 0.040 $Btu/hr.ft^2 \cdot °F$	0.26 $W/m^2.K$ 0.045 $Btu/hr.ft^2 \cdot °F$	0.33 $W/m^2.K$ 0.058 $Btu/hr.ft^2 \cdot °F$	0.33 $W/m^2.K$ 0.058 $Btu/hr.ft^2 \cdot °F$
Interior Wall Construction	Stud Wall w/drywall	Stud Wall w/drywall	Stud Wall w/drywall	light gauge steel stud with Gypsum Dry Wall
Interior Wall U-value	1.56 $W/m^2.K$ 0.274 $Btu/hr.ft^2 \cdot °F$	1.56 $W/m^2.K$ 0.274 $Btu/hr.ft^2 \cdot °F$	1.56 $W/m^2.K$ 0.274 $Btu/hr.ft^2 \cdot °F$	1.86 $W/m^2.K$ 0.328 $Btu/hr.ft^2 \cdot °F$
Roof construction	Wood Truss Roof with exterior insulation with rigid mineral wool above membrane covering between the trusses)	Wood Truss Roof with exterior insulation with rigid mineral wool above membrane covering	Wood Truss Roof with exterior insulation with rigid mineral wool above membrane covering	Concrete roof with rigid foam membrane covering
Roof U value	0.17 $W/m^2.K$ 0.029 $Btu/hr.ft^2 \cdot °F$	0.17 $W/m^2.K$ 0.029 $Btu/hr.ft^2 \cdot °F$	0.17 $W/m^2.K$ 0.029 $Btu/hr.ft^2 \cdot °F$	0.17 $W/m^2.K$ 0.029 $Btu/hr.ft^2 \cdot °F$
Fenestration type	Double glazing (Xtreme, XT II 50/22)	Double glazing (Xtreme, XT II 50/22)	Double glazing (Xtreme, XT II 50/22)	Double glazing (Xtreme, XT II 50/22)

Parameter	Case 1: BamCore Prime Wall	Case 2. Wood with rigid foam	Case 3. Wood without rigid foam	Case 4. Steel Stud infill
Solar Heat Gain Coefficient (SHGC[3])	0.22	0.22	0.22	0.22
Thermal Transmittance (U-value[4])	1.6 $W/m^2.K$ 0.28 $Btu/hr.ft^2\cdot°F\cdot$	1.6 $W/m^2.K$ 0.28 $Btu/hr.ft^2\cdot°F\cdot$	1.6 $W/m^2.K$ 0.28 $Btu/hr.ft^2\cdot°F\cdot$	1.6 $W/m^2.K$ 0.28 $Btu/hr.ft^2\cdot°F\cdot$
Visual Light Transmittance (VLT[5])	46%	46%	46%	46%
Infiltration	1 ach @50 Pa	2 ach @50 Pa	3 ach @50 Pa	3 ach @50 Pa

3.3 Internal loads

The internal loads[6] include occupants, lighting, equipment and appliances. The simulation model needs the intensity of these loads as well as its schedule. All these inputs need to be defined for each of the zones. Below is the summary of inputs for the internal loads.

Table 2: Building energy simulation inputs for internal loads

Zones	Bedroom (for each)	Living, Dining, Family Lounge, Kitchen	Toilet / store
Occupancy load	2 person in one bedroom and 1 person each in remaining bedroom	4 persons	--
Occupancy schedule	**As per given inputs (Annexure)**	**As per given inputs (Annexure)**	--
Lighting load	5.3 W/m2 0.49 W/ft2	5.3 W/m2 0.49 W/ft2	--
Lighting schedule	All Days: Lighting ON 07:00-8:00, 18:00-23:00	All Days: Lighting ON 07:00-8:00, 18:00-23:00	--
Equipment load	Each Bedroom: 50 W	TV: 120 W	--
Equipment schedule	Same as lighting	Same as lighting	--

3.4 Air-conditioning system and operation

The house is considered having operation of air-conditioning system with two scenarios:

Scenario A) The house is fully air-conditioned all the time with no natural ventilation.

Scenario B) The house is fully air-conditioned all the time. Also, use of natural ventilation is considered when it can provide the internal setpoint temperature (During this period the AC remains OFF).

[3] SHGC is the fraction of incident solar radiation admitted through non-opaque components, both directly transmitted, and absorbed and subsequently released inward through conduction, convection, and radiation.
[4] U value is the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side. U value for a wall/ roof/ glazing indicates its ability to transfer heat through conduction.
[5] VLT is the ratio of the total transmitted light to the total incident light. It is a measure of the transmitted light in the visible portion of the spectrum through a material.
[6] The study intentionally precludes additional typical variable loads including electric water heater, refrigerator and kitchen vent chimney etc.

The table below gives details of air-conditioning system, its efficiency, operation schedule, setpoints and control logic for natural ventilation.

Table 3: Building energy simulation inputs for air-conditioning system

Zones	**Bedroom (for each), Living, Dining, Family Lounge, Kitchen**	**Toilet / store**
Conditioned	Yes	Yes
Temperature (Cooling)	24 °C (75 °F)	24 °C (75 °F)
Temperature (Heating)	22 °C (68 °F)	22 °C (68 °F)
Relative Humidity (RH)	No Control	No Control
Fresh air	No mechanical provision	
Natural ventilation control for cooling	**Scenario A)** No Natural Ventilation	
	Scenario B) Jan-Feb, Dec: No Natural Ventilation Mar-Nov: Windows are opened if, it fulfils three conditions 1) T_{inside} > $T_{outside}$ 2) T_{inside} > 20 °C and 3) Natural ventilation is able to meet the cooling setpoint i.e. 24 °C	
Air Conditioning Schedule	**Scenario A)** Jan-Feb, Dec: Heating 24x7 (No cooling, No Natural Ventilation) Mar-Nov: Cooling 24x7 (No heating, No Natural Ventilation)	
	Scenario B) Jan-Feb, Dec: Heating 24 x 7 (No cooling, No Natural Ventilation) Mar-Nov: Cooling 24 x 7 (Natural Ventilation is priority, No Heating)	
System type	Split / multi-split with cooling and heating	Split / multi-split with cooling and heating
Cooling Coefficient of Performance (COP) (W/W)	3.5 (15 SEER/12 EER)	3.5 (15 SEER/12 EER)
Heating Coefficient of Performance (COP) (W/W)	3.8 (8.8 HSPF)	3.8 (8.8 HSPF)
Schedule	24x7	24x7

Notes:

- Cooling COP: It is the ratio of heat removed from the conditioned area to the electric power input. A cooling COP of 3.5 means, the system will remove 3.5 W of heat from the space using 1 W of electricity.
- Heating COP: It is the ratio of heat supplied to the conditioned area to the electric power input. A heating COP of 3.8 means, the system supply 3.8 W of heat to the space using 1 W of electricity.

This completes all the inputs for energy simulation.

4. Thermal impact calculation and results

Based on the details mentioned in Chapter 2 and Chapter 3, the energy simulation model has been finalized. The simulation runs were done using DesignBuilder which gave the hourly / daily / monthly results for all the desired parameters. The simulation and subsequent calculation were done for the four walling systems:

- Case.1: BamCore Prime Wall System
- Case.2: Wood with rigid foam
- Case.3: Wood without rigid foam
- Case.4: Steel Stud infill

4.1 Operational energy

Scenario A)

Case.1 showed a saving of 4% and 3% in overall operational energy as compared to Case.3 and Case.4 respectively, while it was very close to Case.2. The detailed results for all four cases are shown in both, tabular and graphical format, below.

Table 4 *Scenario A:* Annual energy consumption for the four cases

	Case.1_Prime Wall	Case.2_Wood with rigid foam	Case.3_Wood without rigid foam	Case. 4_Steel Stud infill
Room Electricity (kWh/y)	2,957	2,957	2,957	2,957
Lighting (kWh/y)	6,346	6,346	6,346	6,346
Heating + Cooling Electricity (kWh/y)	8,568	8,644	9,225	9,144
Total (kWh/y)	**17,870**	**17,946**	**18,528**	**18,446**
Energy Performance Index (EPI*) (kWh/m^2.y)	**32**	**33**	**34**	**34**

* The EPI calculation is based on the built-up area of 550 m^2. EPI is the total energy consumed in a building over a year divided by total built-up area.

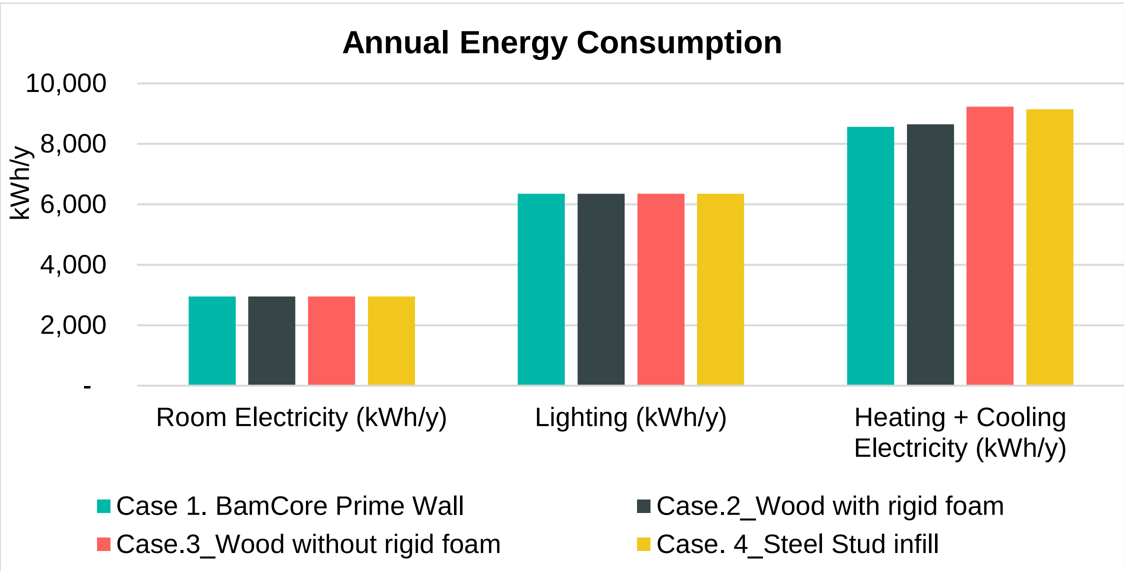


Figure 4 *Scenario A:* Annual energy consumption for the four cases

Scenario B)
Case.1 showed a saving of ~6% in overall operational energy as compared to Case.3 and Case.4, while Case.1 showed a saving of ~3% in overall operation energy as compared to Case.2. The detailed results for all four cases are shown in both, tabular and graphical format, below.

Table 5: *Scenario B:* Annual energy consumption for the four cases

	Case.1_Prime Wall	Case.2_Wood with rigid foam	Case.3_Wood without rigid foam	Case. 4_Steel Stud infill
Room Electricity (kWh/y)	2,957	2,957	2,957	2,957
Lighting (kWh/y)	6,346	6,346	6,346	6,346
Heating + Cooling Electricity (kWh/y)	6,037	6,473	7,069	6,997
Total (kWh/y)	**15,339**	**15,775**	**16,371**	**16,299**
Energy Performance Index (EPI*) (kWh/m².y)	**28**	**29**	**30**	**30**

* The EPI calculation is based on the built-up area of 550 m². EPI is the total energy consumed in a building over a year divided by total built-up area.

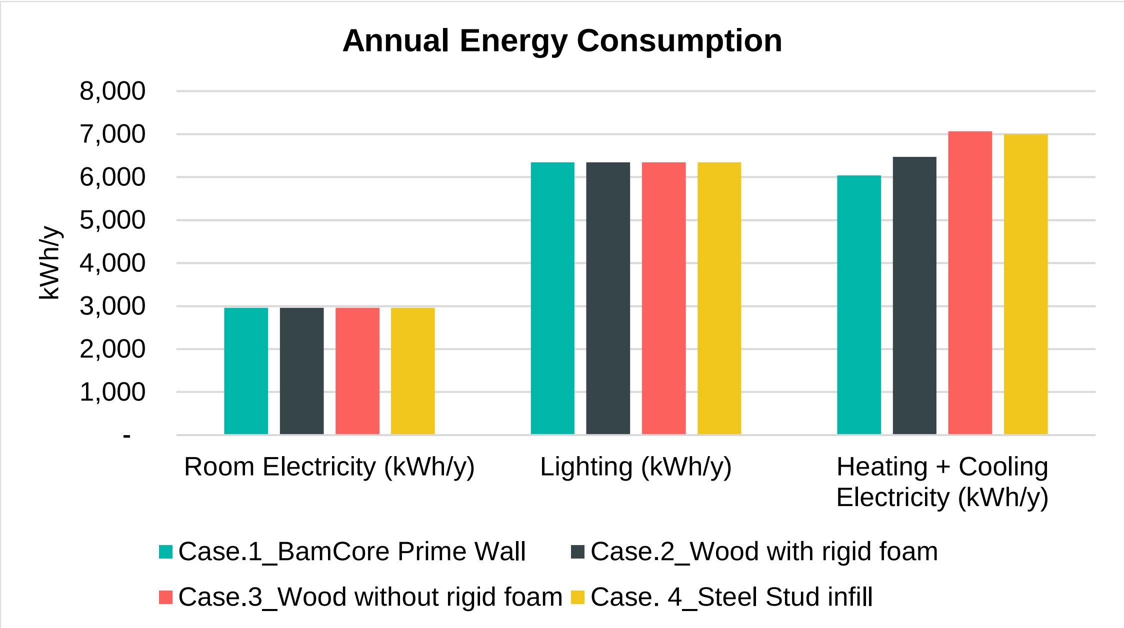


Figure 5: *Scenario B:* Annual energy consumption for the four cases

4.2 Air-conditioning energy

Scenario A)
Except the building envelope, all other inputs for all four cases remained the same. Hence, only the air-conditioning energy will change for the four cases and the impact will vary based on the season. Case.1 showed a saving of 8% and 7% in air-conditioning energy as compared to Case.3 and Case.4 respectively, while Case.1 showed a saving of 1% in air-conditioning energy as compared to Case.2. The month-wise air conditioning energy results for all four cases are shown in graphical format while the annual air-conditioning results are shown in tabular format.

Table 6 *Scenario A:* Annual air-conditioning energy consumption for the four cases

	Cooling+ Heating (kWh/y)
Case.1_BamCore Prime Wall	8,568
Case.2_Wood with rigid foam	8,644
Case.3_Wood without rigid foam	9,225
Case. 4_Steel Stud infill	9,144

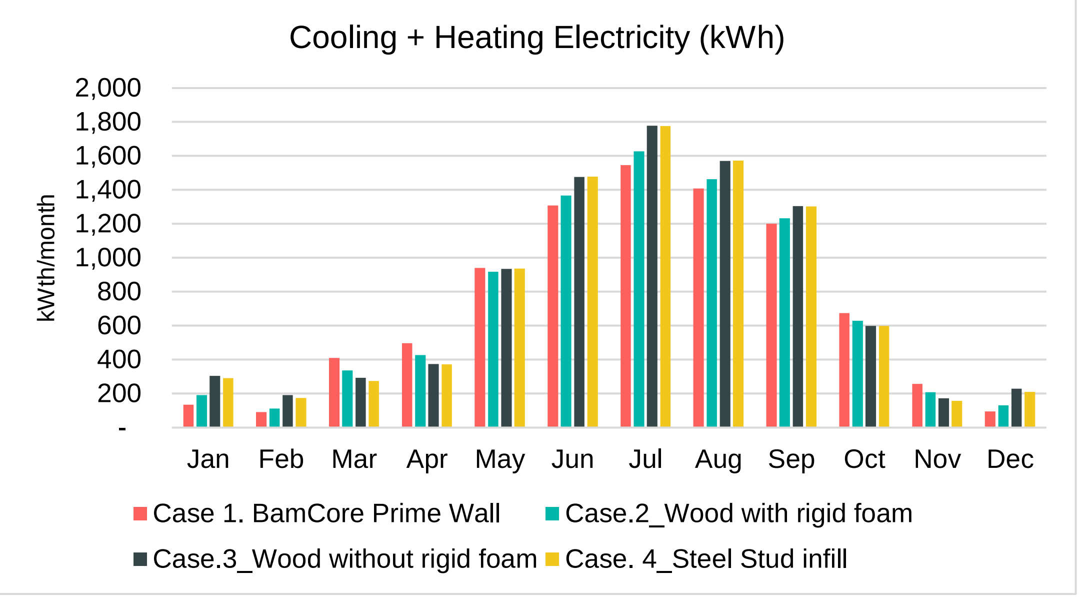


Figure 6 *Scenario A*: Monthly air-conditioning energy consumption for the four cases

Scenario B)

Except the building envelope, all other inputs for all four cases remained same. Hence, only the air-conditioning energy will change for the four cases and the impact will vary based on the season. Case.1 showed a saving of 17% and 16% in air-conditioning energy as compared to Case.3 and Case.4 respectively, while Case.1 showed a saving of 7% in air-conditioning energy as compared to Case.2. The month-wise air conditioning energy results for all four cases are shown in graphical format while the annual air-conditioning results are shown in tabular format.

Table 7 *Scenario B:* Annual air-conditioning energy consumption for the four cases

	Cooling+ Heating (kWh/y)
Case.1_BamCore Prime Wall	6,037
Case.2_Wood with rigid foam	6,473
Case.3_Wood without rigid foam	7,069
Case. 4_Steel Stud infill	6,997

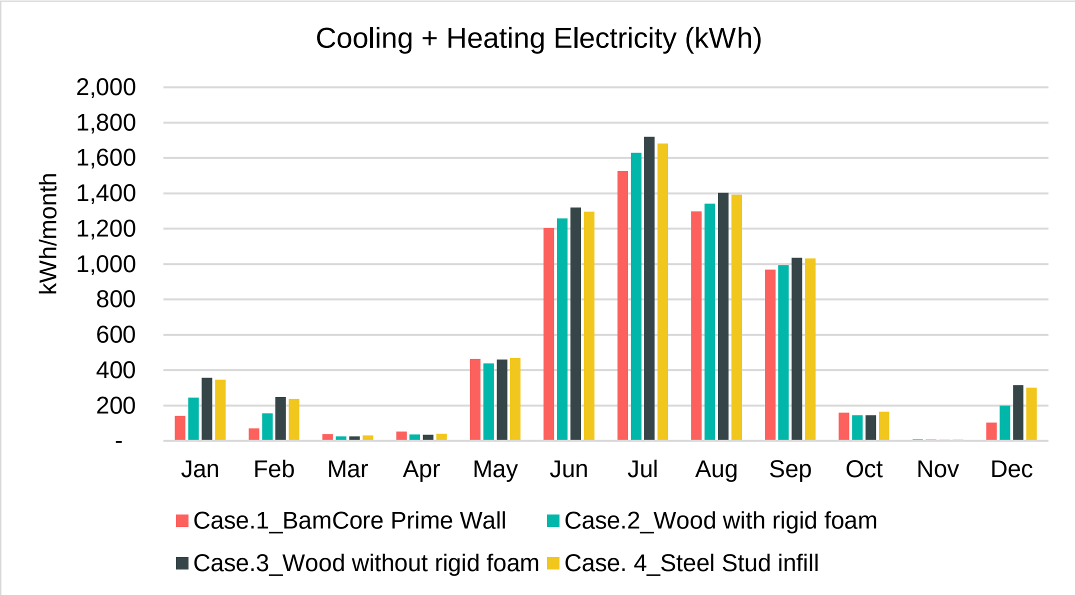


Figure 7: *Scenario B*: Monthly air-conditioning energy consumption for the four cases

4.3 Air-conditioning system size

While the efficient building envelope helps in reducing the energy consumption, it also helps in peak cooling / heating requirements; and hence, reduction in the required cooling and heating system capacity to provide thee setpoint. This also helps in reduction in capital cost of the air-conditioning system as well as associated electrical system (contract demand, wiring, power backup, etc.).

Scenario A) & B)
Case.1 showed a reduction of 12% and 15% in air-conditioning system size as compared to Case.3 and Case.4, while Case.1 showed a reduction of 5% in air-conditioning system size as compared to Case.2. The results for all four cases are shown in both, tabular and graphical format, below.

Table 8: Air-conditioning system size for the four cases

	Case.1_Prime Wall	**Case.2_Wood with rigid foam**	**Case.3_Wood without rigid foam**	**Case. 4_Steel Stud infill**
Cooling System Size (kW)	15	16	17	17
Heating System Size (kW)	10	12	14	14

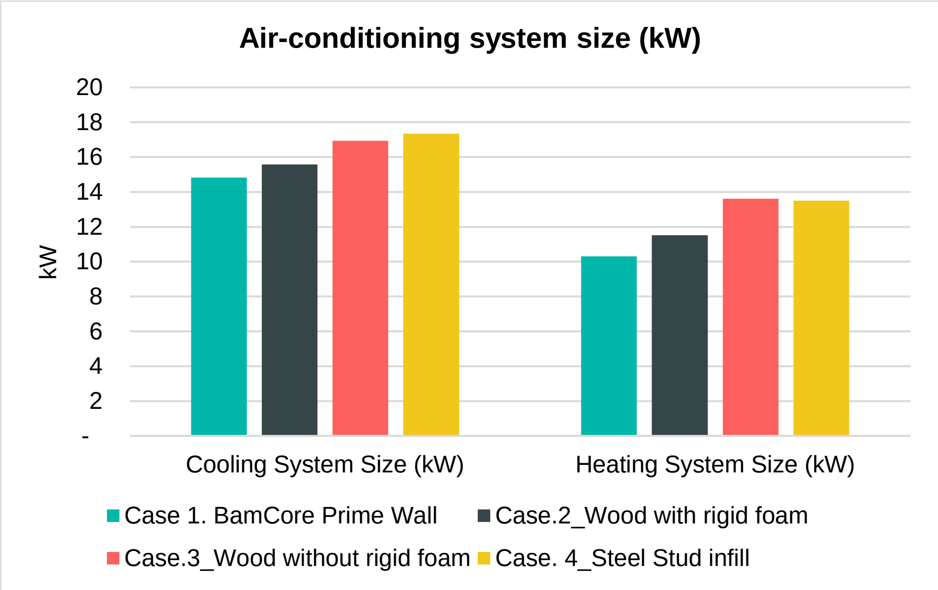


Figure 8: Air-conditioning system size for the four cases

5. Carbon calculation and results

The carbon calculation included the impact of embodied carbon and operational carbon for the four cases.

5.1 Embodied carbon calculation

5.1.1 Methodology and references

Calculation methodology for embodied carbon is explained below and all the references used for calculation are also given.

- Estimation of material quantities: The first step is to estimate the quantity of each type of material used for the building construction. This is done based on the architectural drawings and typical thumb rules.
- Calculations undertaken within the system boundary of cradle to gate, as defined in standard ISO 14044.
- Embodied carbon for each material is taken from multiple references as shown in Annexure I.
- Embodied carbon numbers of all 4 wall assemblies are provided by BamCore team. Also, shown in Annexure I.
- With all the material quantities and its respective embodied carbon, the embodied carbon for the house has been calculated for all four cases.
- The embodied carbon is calculated per unit meter square of wall area or per unit mass of the component used in construction of the house.

5.1.2 Embodied carbon results

The tables below show the calculation details and results for embodied carbon for all four cases. All 4 cases include quantity of steel and cement required for the foundation, and the corresponding embodied carbon is added in all four cases given below.

Table 9: Embodied carbon calculations for Case.1_BamCore Prime

Type	**Quantity**	**Unit**	**Weight (kg)**	**Weight (lb)**	**Embodied carbon kg CO_2/kg**	**Net Embodied carbon kg CO_2/m^2**	**Total embodied carbon (tonne)**
Foundation and Column Concrete	12,113	kg	12,113	26,681			2.22
Foundation and Column Rebar	681	kg	681	1,499			0.58
Bottom floor Slab	110	m^2				91.85	10.10
External wall: Bamcore assembly with 6.67% framing factor, fibreglass insulation, 20mm gypsum each face	786.30	m^2				-32.25	-25.36
Internal wall	396.28	m^2				-2.87	-1.14
Roof	110	m^2				-10.05	-1.11
Internal floor	440	m^2				-21.39	-9.41
Glass (6mm thk) in openings	931.73	kg	931.73		1.27		1.18
				TOTAL			**-22.93**

Table 10: Embodied carbon calculations for Case.2_Wood with rigid foam

Type	Quantity	Unit	Weight (kg)	Weight (lb)	Embodied carbon kg CO_2/kg	Net Embodied carbon kg CO_2/m^2	Total embodied carbon (tonne)
Foundation and Column Concrete	12,113	kg	12,113	26,681			2.22
Foundation and Column Rebar	681	kg	681	1,499			0.58
Bottom floor Slab	110	m^2				91.85	10.10
External wall: Bamcore assembly with 6.67% framing factor,fiberglass insulation, 20mm gypsum each face	786.30	m^2				-26.06	-20.49
Internal wall	396.28	m^2				-2.87	-1.14
Roof	110	m^2				-10.05	-1.11
Internal floor	440	m^2				-21.39	-9.41
Glass (6mm thk) in openings	931.73	kg	931.73		1.27		1.18
				TOTAL			**-18.05**

Table 11: Embodied carbon calculations for Case.3_Wood without rigid foam

Type	Quantity	Unit	Weight (kg)	Weight (lb)	Embodied carbon kg CO_2/kg	Net Embodied carbon kg CO_2/m^2	Total embodied carbon (tonne)
Foundation and Column Concrete	12,113	kg	12,113	26,681			2.22
Foundation and Column Rebar	681	kg	681	1,499			0.58
Bottom floor Slab	110	m^2				91.85	10.10
External wall	786.30	m^2				-29.58	-23.26
Internal wall	396.28	m^2				-2.87	-1.14
Roof	110.00	m^2				-10.05	-1.11
Internal floor	440.00	m^2				-21.39	-9.41
Glass (6mm thk) in openings	931.73	kg	931.73		1.27		1.18
				TOTAL			**-20.83**

Table 12 Embodied carbon calculations for Case. 4_Steel Stud infill

Type	Quantity	Unit	Weight (kg)	Weight (lb)	Embodied carbon kg CO_2/kg	Net Embodied carbon kg CO_2/m^2	Total embodied carbon (tonne)
Foundation and Column Concrete	59,837	kg	59,837	1,31,800			10.99
Foundation and Column Rebar	3,362	kg	3,362	7,405			2.87
Bottom floor Slab	110	m^2				91.85	10.10
External wall	786.30	m^2				85.39	67.14
Internal wall	396.28	m^2				20.87	8.27
Roof	110.00	m^2				94.37	10.38
Internal floor	440.00	m^2				67.45	29.68
Glass (6mm thk) in openings	931.73	kg	931.73		1.27		1.18
				TOTAL			**140.62**

Case.1 showed a significant reduction in embodied carbon as compared to the fourth case (116%). The results for all four cases are shown in both, tabular and graphical format, below.

Table 13: Embodied carbon for the four cases

Type	Total embodied carbon (tonne)
Case.1_BamCore Prime Wall	**-22.93**
Case.2_Wood with rigid foam	**-18.05**
Case.3_Wood without rigid foam	**-20.83**
Case.4_Steel Stud infill	**140.62**

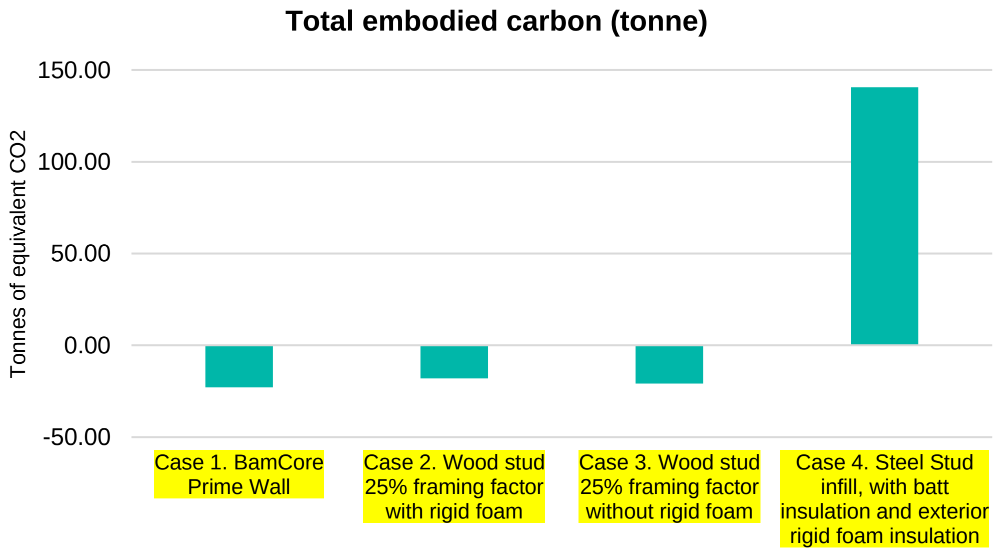


Figure 9: Embodied carbon for the four cases

5.2 Operational carbon calculation

5.2.1 Methodology and references

Calculation methodology for operational carbon is explained below and all the references used for calculation are also given.

- All the energy consumption is taken from the energy simulation results done for the four cases.
- Building life is considered as 50 years.
- Average grid emission factor[7] is taken as 0.39 kg.CO_2/kWh.
- With all the energy consumption numbers and the grid emission factor, the operational carbon for the house has been calculated for all four cases.

5.2.2 Operational carbon results

Scenario A)

Case.1 showed a saving of close to 3.4% in overall operational energy as compared to Case.3 and Case.4, while Case.1 showed no significant savings in overall operation energy as compared to Case.2. The detailed results for all three cases are shown in both, tabular and graphical format, below.

Table 14 *Scenario A:* Operational carbon results for all four cases

Type	Operational carbon (tonne/y)	Operational carbon, lifetime (50 y) (tonne)
Case.1_BamCore Prime Wall	6.95	348
Case.2_Wood with rigid foam	6.98	349
Case.3_Wood without rigid foam	7.21	360
Case. 4_Steel Stud infill	7.17	359

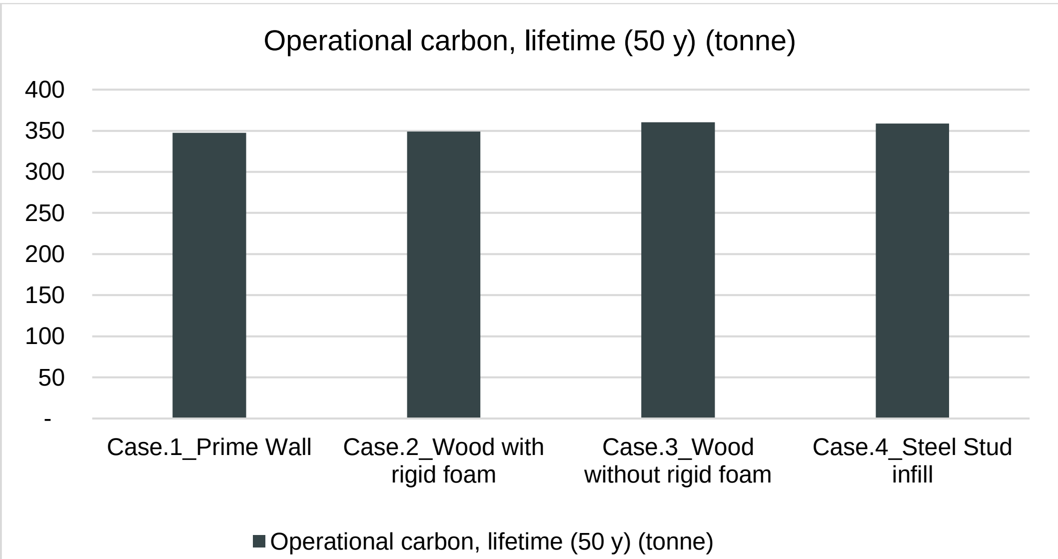


Figure 10: *Scenario A:* Operational carbon results for all four cases

[7] Source: https://www.carbonfootprint.com/docs/2022_03_emissions_factors_sources_for_2021_electricity_v11.pdf

Scenario B)

Case.1 showed a saving of close to 7% in overall operational energy as compared to Case.3 and Case.4, while Case.1 showed a saving of around 3% in overall operation energy as compared to Case.2. The detailed results for all three cases are shown in both, tabular and graphical format, below.

Table 15: *Scenario B:* Operational carbon results for all four cases

Type	**Operational carbon (tonne/y)**	**Operational carbon, lifetime (50 y) (tonne)**
Case.1_BamCore Prime Wall	5.97	298
Case.2_Wood with rigid foam	6.14	307
Case.3_Wood without rigid foam	6.37	318
Case. 4_Steel Stud infill	6.34	317

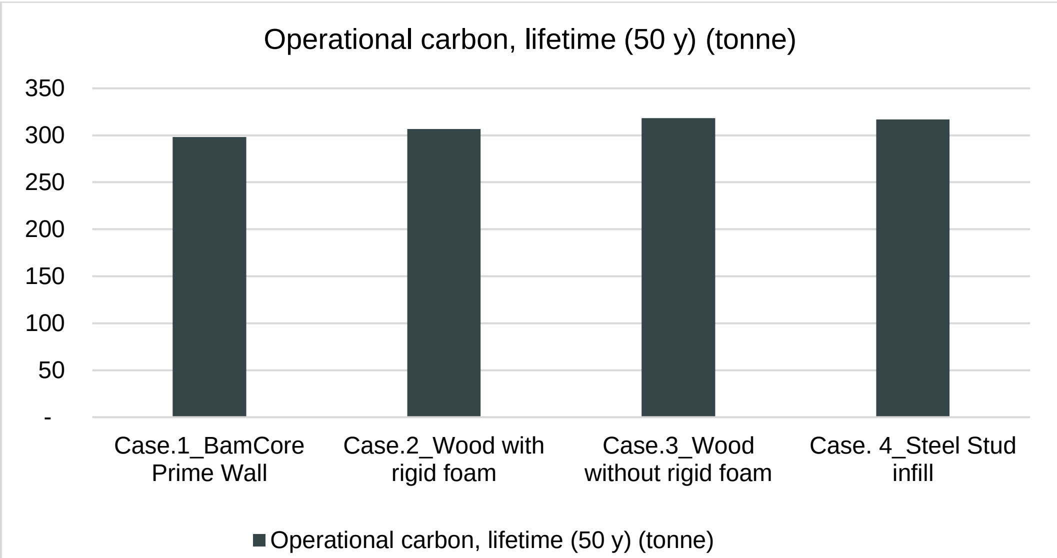


Figure 11: *Scenario B:* Operational carbon results for all four cases

5.3 Total carbon calculation

Scenario A)

The total carbon for this calculation is taken as the addition of embodied carbon and the operational carbon the building lifetime. Case.1 showed a reduction of 35% in total carbon as compared to Case.4, while Case.1 showed a reduction of 4% and 2% in total carbon as compared to Case.3 and Case.2 respectively. The detailed results for all four cases are shown in both, tabular and graphical format, below.

Table 16: *Scenario A:* Total carbon calculation results for all four cases

	Embodied carbon (tonne)	Operational Carbon, lifetime (tonne)	Total Carbon (tonne)
Case.1_BamCore Prime Wall	-23	298	275
Case.2_Wood with rigid foam	-18	307	289
Case.3_Wood without rigid foam	-21	318	297
Case. 4_Steel Stud infill	141	317	458

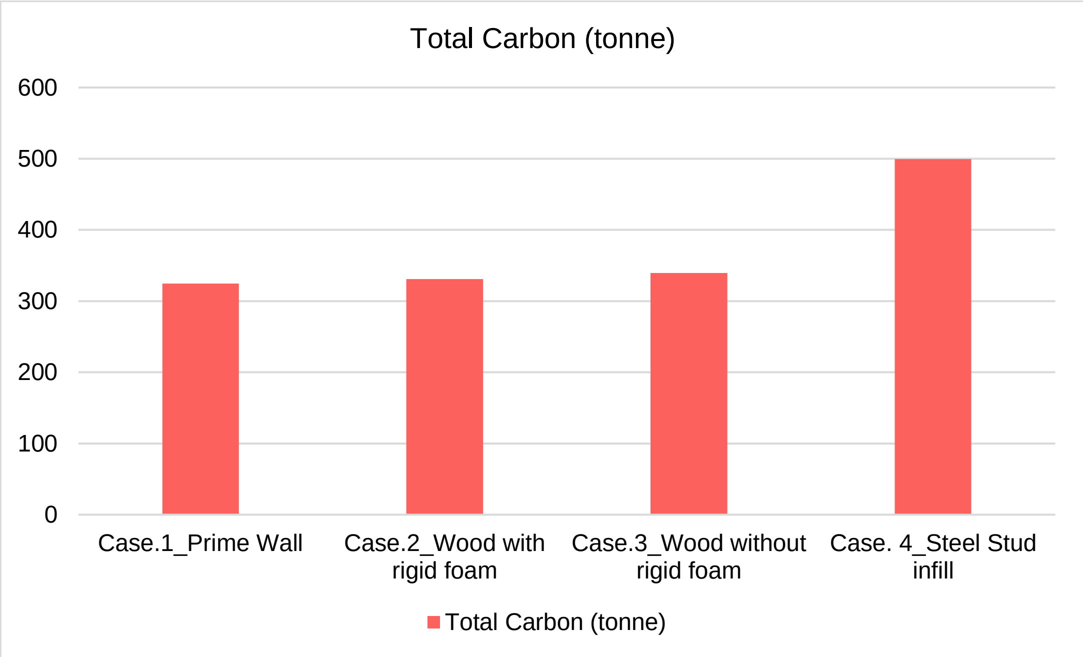


Figure 12: *Scenario A:* Total carbon calculation results for all four cases

Scenario B)

The total carbon for this calculation is taken as the addition of embodied carbon and the operational carbon the building lifetime. Case.1 showed a reduction of 40% in total carbon as compared to Case.4, while Case.1 showed a reduction of 7% and 5% in total carbon as compared to Case.3 and Case.2 respectively. The detailed results for all four cases are shown in both, tabular and graphical format, below.

Table 17: *Scenario B:* Total carbon calculation results for all four cases

	Embodied carbon (tonne)	Operational Carbon, lifetime (tonne)	Total Carbon (tonne)
Case.1_BamCore Prime Wall	-23	298	275
Case.2_Wood with rigid foam	-18	307	289
Case.3_Wood without rigid foam	-21	318	297
Case. 4_Steel Stud infill	141	317	458

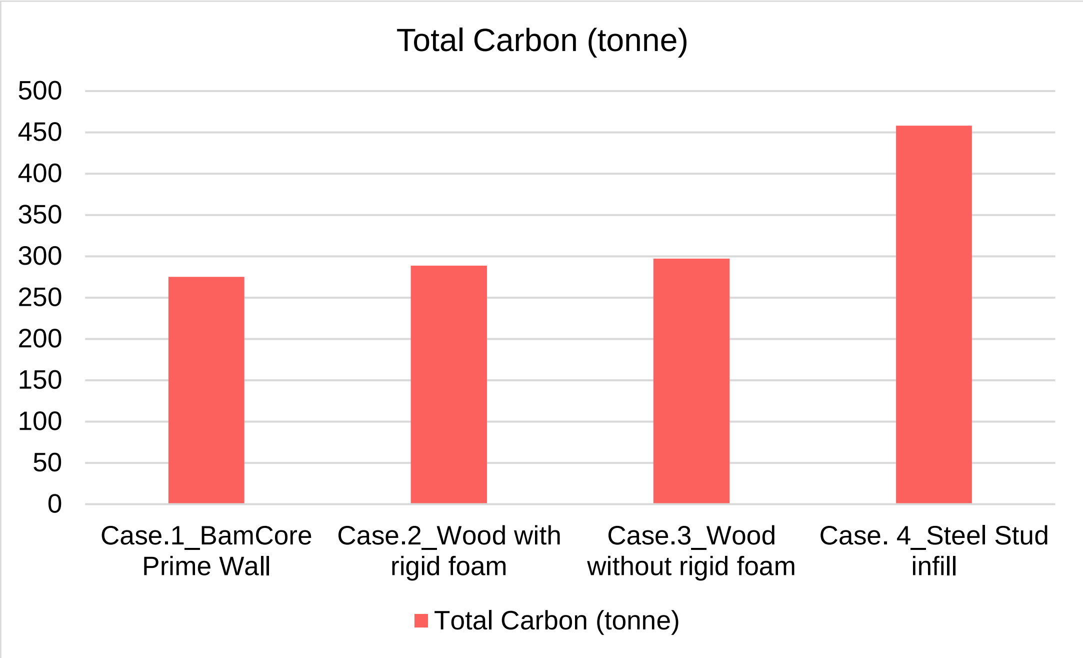


Figure 13: *Scenario B:* Total carbon calculation results for all four cases

Annexure I: References for embodied carbon and Occupancy Schedule

Walling assembly	Net Carbon ($kgCO_2/m^2$)	Embodied Carbon ($kgCO_2/m^2$)	Stored Biogenic Carbon Wood ($kgCO_2/m^2$)
Bamcore assembly with 6.67% framing factor, fibreglass insulation, 20mm gypsum each face	-32.25	33.82	-66.07
External Wood Wall, 25% FF with EPS Foam	-26.06	17.11	-43.16
External Wood Wall, 25% FF without EPS Foam	-29.58	13.58	-43.16
Steel Studs with 25% FF with EPS Foam	58.80	58.80	0.00

Bedroom Occupancy schedule			**Living Space Occupancy schedule**		
For 4 people			**For 4 people**		
Schedule:Compact,			Schedule:Compact,		
Dwell_DomBed_Occ,			Dwell_DomDining_Occ,		
Fraction,			Fraction,		
Through:	31	Dec,	Through:	31	Dec,
For:	Weekdays,		For:	Weekdays,	
Until:	06:00,	1,	Until:	06:00,	0,
Until:	07:00,	0.5,	Until:	07:00,	0.5,
Until:	08:00,	0.25,	Until:	10:00,	0.75,
Until:	21:00,	0,	Until:	15:00,	0.5,
Until:	23:00,	0.25,	Until:	19:00,	0.75,
Until:	24:00,	0.75,	Until:	21:00,	1,
For:	Weekends,		Until:	22:00,	0.75,
Until:	07:00,	1,	Until:	24:00,	0.25,
Until:	08:00,	0.75,	For:	Weekends,	
Until:	09:00,	0.5,	Until:	07:00,	0,
Until:	10:00,	0.25,	Until:	08:00,	0.25,
Until:	21:00,	0,	Until:	09:00,	0.5,
Until:	22:00,	0.25,	Until:	10:00,	0.75,
Until:	24:00,	0.75,	Until:	14:00,	0,
For:	AllOtherDays,		Until:	21:00,	1,
Until:	07:00,	1,	Until:	22:00,	0.5,
Until:	08:00,	0.75,	Until:	24:00,	0.75,
Until:	09:00,	0.5,	For:	AllOtherDays,	
Until:	10:00,	0.25,	Until:	07:00,	0,
Until:	21:00,	0,	Until:	08:00,	0.25,
Until:	22:00,	0.25,	Until:	09:00,	0.5,
Until:	24:00,	0.75;	Until:	10:00,	0.75,
			Until:	14:00,	0,
			Until:	21:00,	1,
			Until:	22:00,	0.5,
			Until:	24:00,	0.75;