Airtightness or Wall Insulation: Where to Put your Budget First?

How can we make the most of our limited construction budgets? Both our health and wallet are crucial parameters in design and construction of a new home. The researchers compared two related approaches towards a comfortable home: airtightness and wall insulation.

A reasonable question to be considered in this regards is, "Why pay to heat and cool your home and then just let the air leak out?"

In Canada, people spend approximately 90 percent of their time indoors [1].

"*In a way, the buildings in which we choose to live our lives are very much a kind of 'third skin.' and are of critical importance to our health and well-being.*"- Lloyd Lee [2]

The first skin is the human skin that regulates body temperature, and the second is the clothes we wear, which gives comfort and protection. We can choose to wear what we need based on the situation, such as a winter coat for cold weather, breathable clothing for the tropical climate, and a raincoat for preventing soaking. The third skin is what makes our home, the building envelope that includes walls, roof, openings (doors, windows), and floors [2].

Building envelope controls temperature, water, air, and vapour by controlling the air infiltration and exfiltration [3]. Researchers have found that, besides continuous insulation, better airtightness and reduced number of thermal bridges (Figure 1), are crucial to reducing heat loss. [4, 5].

A house is not merely a shelter. A well-designed and better-constructed dwelling can significantly reduce the negative environmental impacts such as CO_2 emission, create a livable environment, and above all, ensure occupants' comfort and well-being.

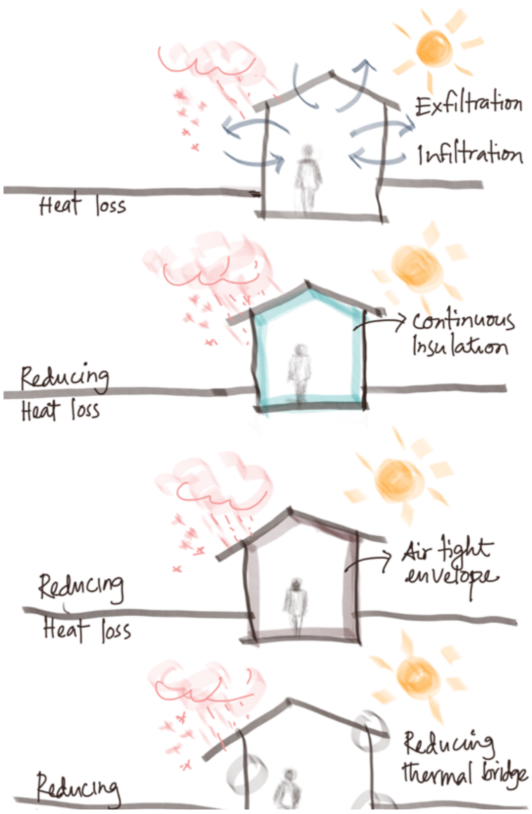


Figure 1. Building envelope and factors contributing to heat loss reduction

What is Airtightness?

Airtightness is a widely used term that measures how much air is leaking into a building or out from a building envelope [6]. It can be defined as the resistance of infiltration and/or exfiltration of conditioned or treated air through the gaps, joints, or cracks of the building envelope. Its primary focus is to keep conditioned air inside and unconditioned air outside. Air leakage should not be confused with ventilation [7], as they have different meanings. Ventilation is the controlled flow of air into and out through the designed openings of the building required for the occupants' comfort.

Importance of Airtightness

Appropriate airtightness significantly reduces energy bills [8] and, at the same time, ensures better air quality inside the building. Poor airtightness can be accountable for up to 40% of heat loss from buildings [9]. A lack of proper airtightness can significantly deteriorate a building's performance. Infiltration introduces pollutants, allergens, and microbes into the building. It also results in moisture accumulation.

Potential Air Leakage Paths

There are several potential air leakage paths in residential buildings, such as underfloor ventilation grills, leaky windows/doors, among others (Figure 2). However, these can be avoided through careful design and quality construction practices [8].

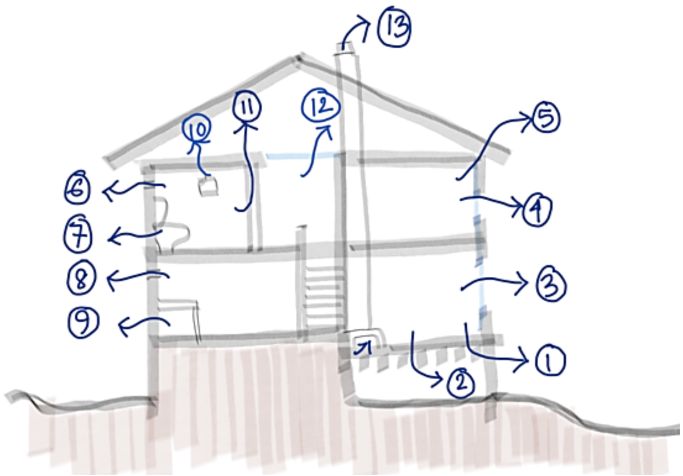


Figure 2. Potential air leakage paths [8]

1. Underfloor ventilation griller
2. Gaps in suspended timber floors
3. Leaky windows
4. Gaps around windows
5. Gaps at the ceiling-to-wall joint
6. Bathroom wall vent
7. Gaps around bathroom waste pipes
8. Kitchen wall vent
9. Gaps around floor-to-wall joint
10. Service penetration
11. Gaps in hollow wall
12. Gaps around loft hatches
13. Open chimneys

Airtightness Measurement

In British Columbia, BC Energy Step Code aims to achieve net-zero energy ready buildings by 2032 through increasingly strict energy use requirements that contain 5 steps. Steps 1, 2, and 3 are the lower energy-efficient steps, and steps 4 and 5 are the most energy-efficient ones. Airtightness is measured in the BC Energy Step Code as air changes per hour (ACH) and is calculated from the hourly airflow at the test pressure of 50 Pascals divided by the building volume [6].

$$ACH_{50} = \frac{\text{Hourly Airflow}_{\text{ at 50 Pascals}}\ (m^3/hr)}{\text{Building Volume}\ (m^3)}$$

The lower ACH indicates better airtightness. The airtightness of the whole building is checked using blower door fans which pressurize and/or depressurize the building. BC Energy Step Code requires the test to be conducted at an induced test pressure of not less than 50 Pascals pressure difference. That is why ACH_{50} value is quite popular.

Table 1 lists the required ACH_{50} values of airtightness in different step codes for part 9 buildings constructed in all climate zones in BC (i.e., zone 4 to 8) [6]:

Table 1. BC Step Codes' requirements for air leakage rate.

Step Code	Airtightness (ACH_{50})
1	No specific target
2	≤ 3.0
3	≤ 2.5
4	≤ 1.5
5	≤ 1.0

Analyses and Results

In Phase I of Wilden Living Lab (WLL), two identical homes were built following different standards. Home of Today (HOD) was built following the BC building code 2012 (The Government of British Columbia, 2020); that represents typical construction practices in Okanagan Valley, and Home of Tomorrow (HOM) was built to higher standard having higher fabric insulation, better performing windows, solar system, and HVAC system consisting of geothermal heat pump. HOD was constructed with wall assemblies with an effective thermal resistance (R) of 17.16 m^2.K/W and HOM was constructed with that of 21.46 m^2.K/W.

To compare the effects of airtightness and wall assemblies on the energy and environmental performances of HOD and HOM, five scenario homes have been modelled and analyzed with HOT2000 energy simulation modelling software as shown in Table 2. The analyses were carried out for total energy consumption that includes both gas and electricity and for total GHG emissions. Scenarios 1 and 2 (S1 and S2) are based on as-built (i.e., actual) airtightness data of the two homes using the blower door test results. The blower door test measured the ACH value of 1.3 for HOD that meets Step Code 4's requirement. The test also measured ACH value of 1.0 for HOM which complies with Step Code 5's requirement. Scenarios 3, 4 and 5 are based on simulations using HOT2000.

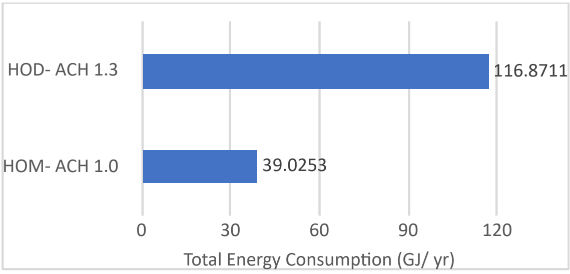
To study the impact of improved airtightness, two scenarios (S3 and S4) were considered. In S3, HOD was analyzed assuming that its actual ACH value was improved to 1.0 (same as actual ACH value of HOM). In S4, HOM was analyzed with a downgraded ACH value of 2.5 (the minimum requirement for Step Code 3). In addition, scenario S5 was studied to identify the effect of improved wall insulation in which HOM was analyzed using the same actual ACH value of 1.0 but the wall was replaced by an upgraded assembly. It should be stressed that this upgraded wall assembly is the same as the one that will also be used in the Next Generation home (i.e., Net-Zero Energy home) in WLL Phase II to achieve an R-value of 25.

Table 2. The analyzed scenario homes.

Scenario #	Scenario Description	Scenario Identifier
S1	Home of Today having ACH value of 1.3	HOD – ACH 1.3
S2	Home of Tomorrow having ACH value of 1.0	HOM – ACH 1.0
S3	Home of Today having ACH value of 1.0	HOD – ACH 1.0
S4	Home of Tomorrow having ACH value of 2.5	HOM – ACH 2.5
S5	Home of Tomorrow having ACH value of 1.0 with the upgraded wall assembly of Next Generation home	HOM – ACH 1.0 – upgraded wall

The results showed savings in annual energy consumption and reduction in carbon emission with improved airtightness.

Figure 3 presents the results of annual energy consumption and Green House Gas (GHG) emission for the as-built homes (S1 and S2). It can be observed that there was 67% reduction in the energy consumption for HOM having an ACH of 1.0 which results in considerable cost savings in the total service life of the home. In addition, due to this significant energy reduction, HOM emits 93% less GHG compared to HOD.



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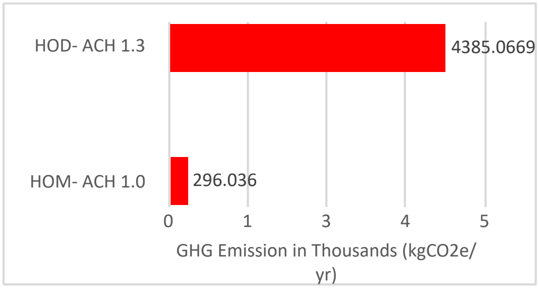
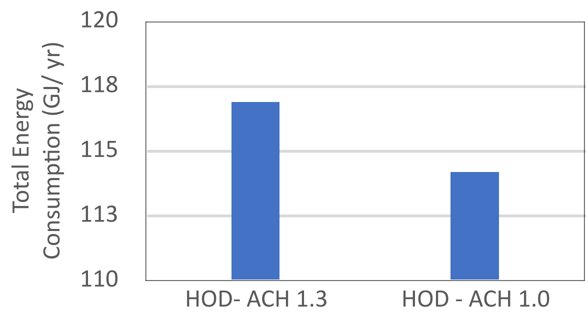


(b)

Figure 3: Comparing (a) total energy consumption and (b) GHG emission between the S1 and S2 homes

Figure 4(a) illustrates the impacts of airtightness on total energy consumption for HOD (S1 to S3) and Figure 4(b) shows that for HOM (S2 to S4). Figure 4(c), on the other hand, examines the effect of improving the wall assembly in HOM (S2 to S5) on the same criteria.



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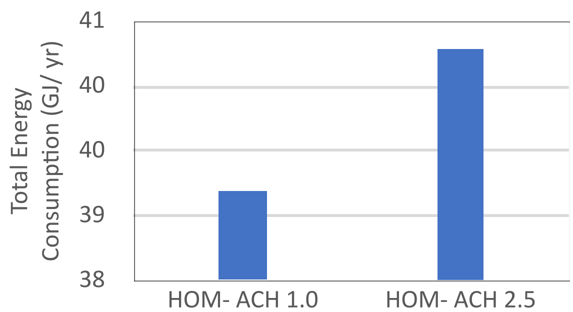

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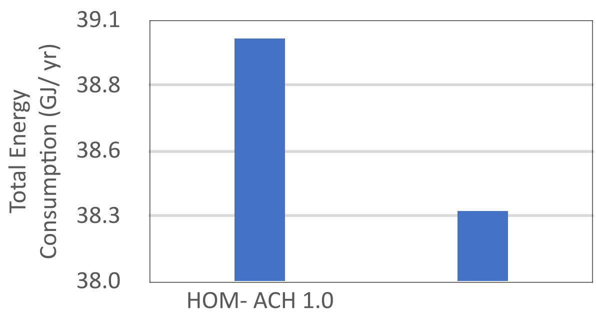

(c)

Figure 4. Comparing total energy consumption between (a) S1 and S3 homes, (b)) S2 and S4 homes, (c) S2 and S5 homes

From Figure 4, it is evident that improving both airtightness and wall assembly yielded in energy savings. Because of airtightness improvement, the reduction in annual energy consumption were 2.35% and 4.22% for HOD and HOM respectively. However, the improved wall assembly resulted in lower energy savings (1.85%) as can be seen from Figure 4(c). The comparison of payback period and GHG emission yielded in more interesting results which are shown in Figure 5.

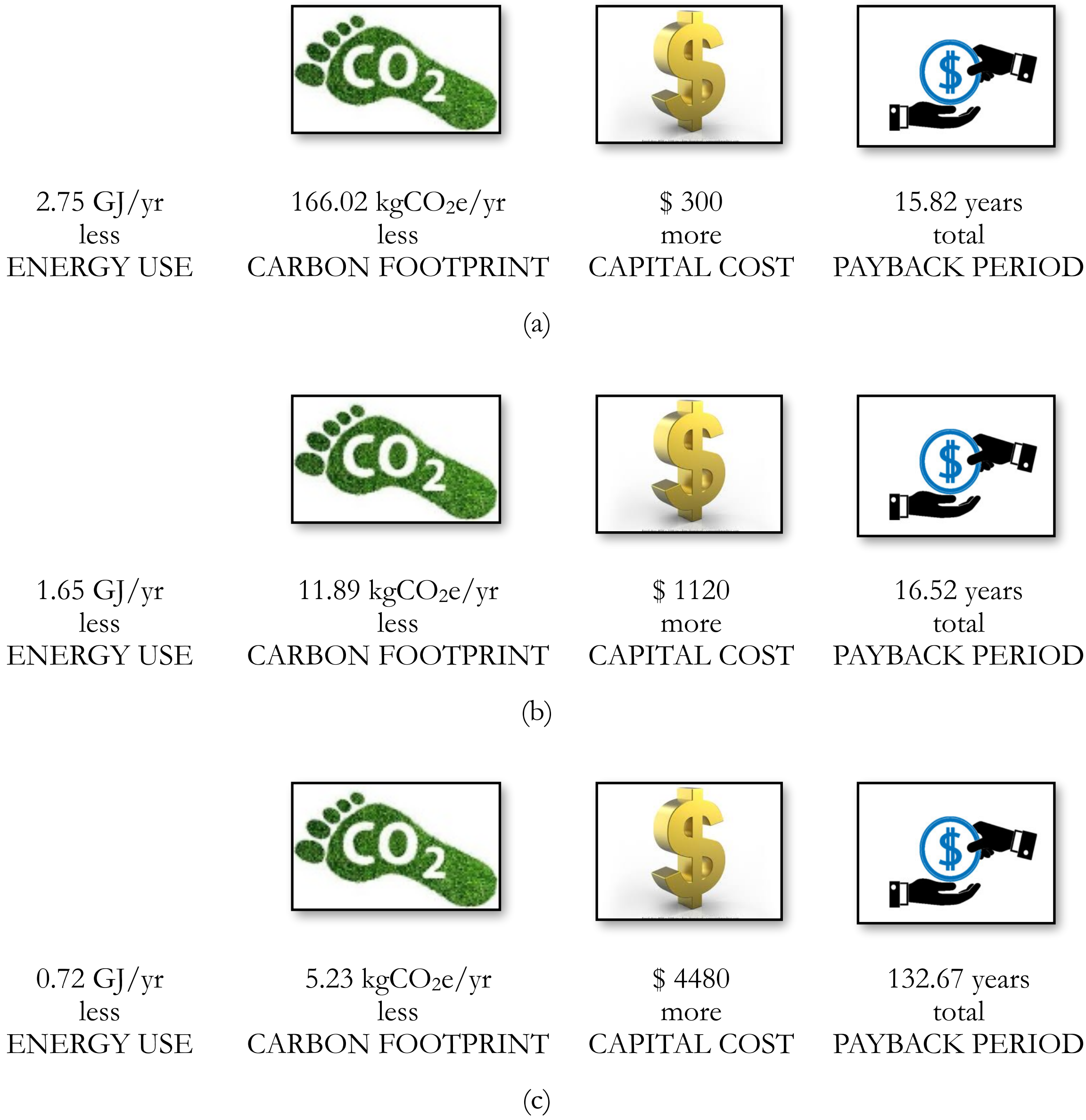

Figure 5. Comparison of energy use, carbon footprint, capital cost and payback period between (a) S1 and S3 homes, (b)) S2 and S4 homes, (c) S2 and S5 homes

From Figure 5(a), it can be observed that improving the airtightness of HOD from ACH 1.3 to ACH 1.0 resulted in 166.02 $kgCO_2e$ less GHG emission in addition to 2.75 GJ savings in annual energy use. The payback period for this upgrade is 15.82 years. Upgrading the airtightness of HOM from 2.5 to 1.0 brought about 12 $kgCO_2e$ reduction in GHG emission and had a payback period of 16.5 years as can be revealed from Figure 5(b). On the contrary, retrofitting the HOM with upgraded wall assembly needed the highest investment and consequently the highest payback time, although it performed the worst in terms of energy consumption and GHG reduction. This is evident from Figure 5(c). Upgrading the HOM with better wall assembly pays back in 132.67 years which is around 8 times more than investing into airtightness.

Conclusion

The annual energy consumption and the consequent environmental burdens can be significantly decreased by improving the airtightness in single-family detached homes (SFDH). According to the analyses in this blog, the improved airtightness of the Home of Today and the Home of Tomorrow resulted in better energy and environmental performances with a lower investment. The results also showed that replacing the as-built wall with the upgraded wall assembly, although enhances the energy and environmental performance, requires significantly higher investment and payback time.

Thoroughly sealing the areas where walls, ceilings and foundation of a building envelope are connected is equally, if not more important than the materials we use for the envelope. The airtightness of a building can be improved with excellent workmanship that involves carefully sealing the potential air leakage paths where different assemblies meet. Therefore, we need to plan our homes accordingly before the construction starts because improving the airtightness of an inhabited building is both labor-intensive and expensive task.

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