COMPARISON OF ENERGY USE INDICATORS OF A NON-RESIDENTIAL PASSIVE HOUSE WITH ASHRAE 90.1 BUDGET BUILDING

F. Bagheri[1], M. Fakoor[1], B. Young[1], C. Cranswick[1]

[1]BC Building Science Ltd.
611 Bent Court, New Westminster, BC, Canada
*(*Corresponding author: farshid@bcbuildingscience.com)*

ABSTRACT

Passive house design represents a well-developed approach to arrive at the envelope basis for zero energy building targets. In this paper, a pilot non-residential passive house is studied, and its energy use indicators are compared with ASHRAE 90.1 2010 budget building. A daycare passive house with 375 m^2 floor area located in Penticton, BC, is modelled in IES-VE 2017 and PHPP V9.3 environments and its energy indicators are obtained. Further, an ASHRAE 90.1 2010 budget building of the daycare is modelled in IES-VE 2017 and the results are compared with the passive house. The study includes comparison of heating, cooling, service water heating, lighting, receptacle, and auxiliary energy intensities of the passive house and the budget building. In addition, the results from IES-VE and PHPP models are compared. Thermal energy demand intensity (TEDI) and total energy use intensity (TEUI) are also obtained and compared between the passive house and the budget building. The effects of external shading, and type of heating system on energy intensity of the passive house, is studied

KEYWORDS: Passive House, Energy Use Indicators, ASHRAE 90.1 Budget Building

7 INTRODUCTION

Residential, commercial / institutional, industrial, transportation, and agriculture sectors consumed 8,924 PJ total secondary energy in Canada in 2013. A total of 487 Mt of GHG was released from this total secondary energy consumption. Residential and commercial / institutional buildings consumed 17% and 10% of the total secondary energy of Canada in 2013, respectively (Natural Resources Canada, 2016).

In 2016, a total of 704 Mt of GHG was released to atmosphere in Canada. The entire building sector released 81.4 Mt of GHG equivalent to 11.6% of country's total GHG emissions (Environment and Climate Change Canada, 2018). The government of Canada has aimed to reduce GHG by 80% below 2005 level until 2050. Therefore, improvement of energy efficiency in building sector can play a significant role in reduction of energy consumption and the associated GHG emissions.

The American National Standards Institute (ANSI); American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE); and the Illuminating Engineering Society (IES) have established an Energy Standard for Buildings Except Low-Rise Residential Buildings "ANSI / ASHRAE / IES Standard 90.1" that has been contributing significantly in energy performance improvement of buildings in North America (ANSI/ASHRAE/IES, 2010). The ANSI/ASHRAE/IES Standard 90.1 (referred to as ASHRAE 90.1 in this paper) requires that any proposed building at design stage, that cannot meet its minimum (prescriptive) requirements of envelope/mechanical/electrical, be modelled and its energy consumption be calculated.

The standard requires that the proposed building be at least as energy efficient as a virtual "Budget Building" that is also modelled based on specifications of the proposed building. This method is called Energy Cost Budget (ECB) method (ANSI/ASHRAE/IES, 2010). The budget building has a same geometry (other than fenestration area), space use classification, schedule of operation, thermal blocks, and HVAC zones as the proposed building; however, the envelope, HVAC, service hot water, and lighting systems meet the Standard's prescriptive efficiency requirements (ANSI/ASHRAE/IES, 2010). As such, the budget building is created virtually in an energy modelling software environment to establish a minimum acceptable benchmark for a proposed building. Based on the ECB method, the building design team modifies the proposed design to achieve at most the energy intensities of the budget building.

The calculation of energy indicators of budget building based on ASHRAE 90.1-ECB has established acceptable energy compliance path for buildings at design stage in many areas of North America during the last decade. However, many areas have been requiring the new construction buildings to outperform the corresponding budget buildings by a specific percentage. Therefore, the ASHRAE 90.1 budget building has been utilized as the most referenced benchmark with minimum acceptable energy performance in the North American building industry thus far.

In addition to establishment of minimum energy requirements by ASHRAE 90.1, the concept and characteristics of Passive House were developed in the last decades to target higher feasible energy efficiency in buildings (Dumont et al., 1978; Shurcliff, 1986; Nissan and Dutt, 1985; Stecher and Klingenberg, 2008; Wright and Klingenberg, 2015; City of Vancouver, 2009). Passive house design represents a well-developed approach to arrive at the envelope basis for zero energy and emission building targets. Passive house design reduces the heat exchange between indoor and outdoor significantly that brings to lower heating and cooling demands and corresponding energy consumptions. In addition, air tight design of passive buildings along with appropriate ventilation optimize the air change requirements to keep an acceptable air quality in breathing zones with the lowest energy consumption.

Even though a passive house design is expected to outperform the budget building design of ASHRAE 90.1, the potential performance improvement from a budget building to passive house design is not clearly known to the building industry. There is a variety of studies focused on different aspects of passive design; however, none of them has focused on detailed comparison of energy components between a passive house and a well-recognized benchmark / reference building such as ASHRAE 90.1 budget building.

Shaviv (Shaviv, 2008) discussed several aspects of a passive and low energy architecture and compared it with a few samples of green architecture with focus on geometry and architects. Orr et al. (Orr et al., 2013) performed field study on air tightness of highly insulated and energy efficient old buildings built between 1979-1992 in Saskatoon. Sadineni et al. (Sadineni et al., 2011) performed a technical review of the building envelope components for passive design that included different types of walls, roofs, and windows, and effects of thermal mass and air tightness.

Our review shows that the literature lacks a comprehensive comparison between a passive house design and ASHRAE 90.1-2010 budget building and detailed evaluation of energy components. Further, there is no study that evaluates the accuracy of data sheet-based energy simulation tool utilized in design and certification of passive house design, Passive House Planning Package (PHPP).

In this paper, a pilot non-residential passive house is studied to evaluate its energy consumption intensities and the existing potential energy savings over ASHRAE 90.1 budget building. As such, Canada's first non-residential passive house with daycare usage is modelled, and the energy consumption intensities are obtained. The passive house is a one storey daycare with 375 m^2 area located in Penticton, BC. The passive house and its ASHRAE 90.1 budget are modelled in IES-VE 2017 software environment and the energy indicators are obtained and compared. Moreover, the passive house is modelled in PHPP V9.3 to compare the results of this energy simulation tool with an hourly analysis simulation program (IES-VE 2017).

This study includes comparison of heating, cooling, service water heating, lighting, and auxiliary energy intensities between the passive house and its ASHRAE 90.1 budget building. In addition, thermal energy demand intensity (TEDI), as the main performance evaluation metric of building envelope and ventilation system, and total energy use intensity (TEUI), as the main overall energy consumption metric, are obtained and compared between the passive house and the ASHRAE 90.1 budget building. The results also include comparison of IES-VE 2017 and PHPP V9.3 outputs as well as parametric study on the effects of external shading and heating system on energy intensity of the passive house.

8 PASSIVE HOUSE SPECIFICATIONS

The selected building for this study is Canada's first non-residential passive house daycare constructed in 2017. Table 1 represents general specifications of the building. Further details are utilized as energy model inputs and tabulated in Appendix A, Table A-1. The building envelope is designed based on high thermal resistivity and air tightness to outperform the minimum requirements of passive house design. Both mechanical and lighting systems are designed based on high efficiency components.

Table 2: General Specifications of the Studied Passive House

Building Application	Non-Residential, Daycare
Building Area	375 m^2
Building Location	Penticton, BC, ASHRAE Climate Zone 5
Year Built	2017
Building Structure	Wood-Framed
Building Mechanical	Heating / Cooling: Variable Refrigerant Flow Air Source Heat Pump Ventilation: Central Heat Recovery Ventilator Service Hot Water: Hybrid Electric Water Heater

9 ENERGY MODELLING

The passive house is modelled in IES-VE 2017 software environment to simulate its hourly energy consumption. Furthermore, a budget building representing the passive house and featuring minimum energy efficiency requirements of ASHRAE 90.1-2010 is modelled in the software for comparison. Figure 1 represents the building model created in IES-VE for this study.

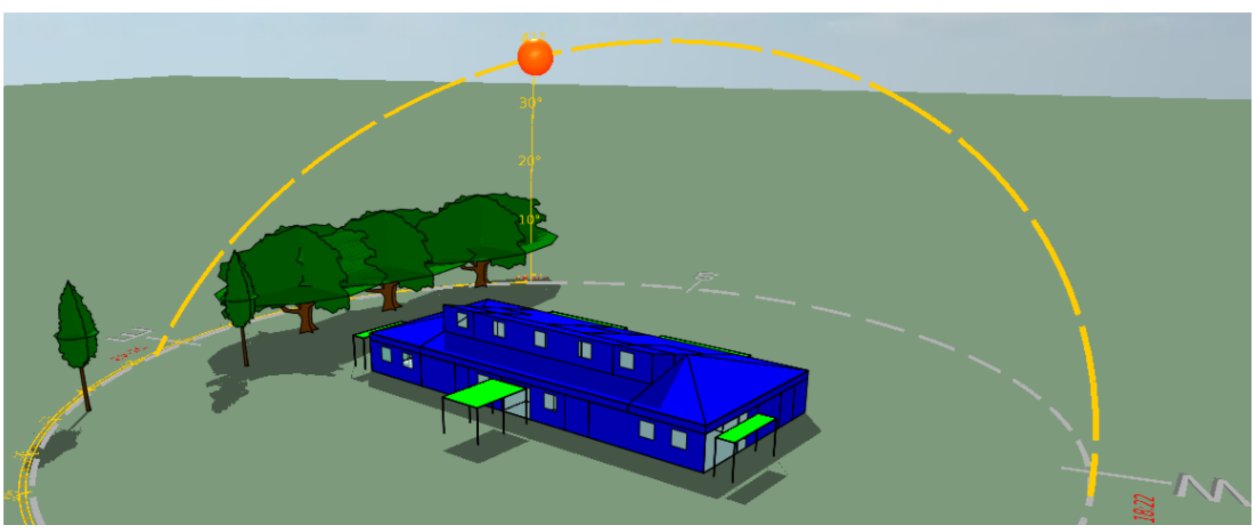

Figure 1: Energy Model Representative of the Passive House in IES-VE 2017

The key model inputs are summarized in Appendix A, Table A-1. In addition to modelling in IES-VE environment, a model of the passive house is created in PHPP V.9.3 environment for a comparison between the results from these two energy modelling software tools.

10 RESULTS AND DISCUSSIONS

The passive house and its corresponding ASHRAE 90.1-2010 budget building are modelled in IES-VE 2017 with a simulation time step of 10 minutes throughout a year and the results are obtained. Table 2 and Figure 2 compare Total Energy Use Intensity (TEUI) and energy breakdown of the passive house and its corresponding ASHRAE 90.1-2010 budget building. Table 2 also compares the passive house and ASHRAE 90.1 budget building from Thermal Energy Demand Intensity (TEDI) perspective.

TEDI represents the yearly summation of space and ventilation heating demands that is independent of the type or efficiency of the mechanical systems in a building. TEDI is a key representative of thermal performance of building envelope and ventilation system that was recently adopted by Building Authorities of British Columbia through BC Energy Step Code (Energy Step Code Council, 2017). A smaller TEDI means a higher thermal performance of building envelope (i.e. higher thermal resistivity) and lower heat demand of ventilation system.

Table 3: Energy Consumption Breakdown [kWh/m^2/y]; Passive vs. Budget Building Designs

Model	Heating	Cooling	Service Hot Water	Lighting	Receptacle/ Equipment	Auxiliary (Fans, Pumps)	TEDI	TEUI
Passive House	4.86	3.33	9.13	5.62	6.28	11.86	15.58	41.07
ASHRAE 90.1-2010 Budget Building	17.53	3.75	26.53	12.15	6.28	12.45	50.55	78.69

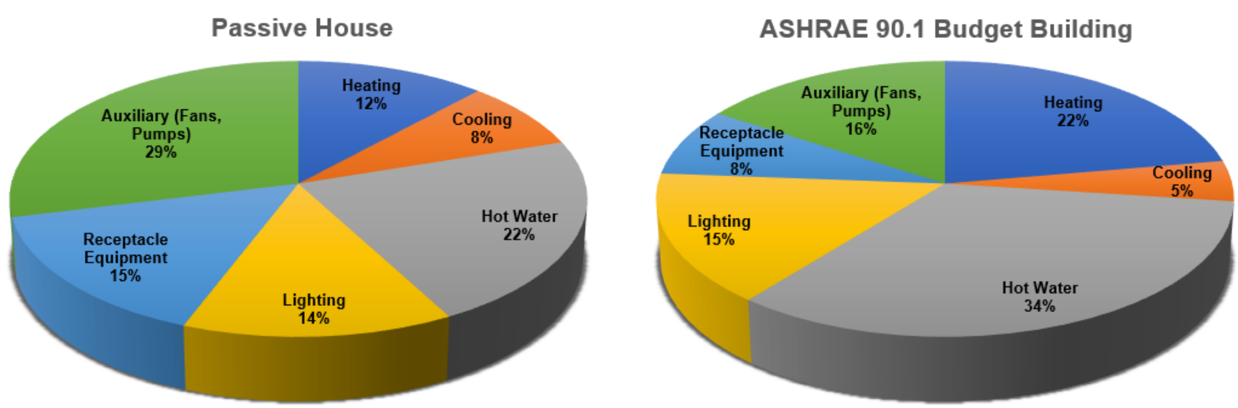

Figure 2: Comparison of Energy Components Between Passive and ASHRAE 90.1 Budget Designs

A comparison between the passive house design and its corresponding ASHRAE 90.1 2010 budget building design shows that the passive building consumes 48% less total energy (TEUI) than the budget building. The significantly lower energy consumption in the passive design is due to envelope components with higher thermal performance; higher efficiency heating, ventilation, and air conditioning (HVAC) system; and higher efficiency service water heating and lighting systems in the passive house compared to ASHRAE 90.1-2010 minimum requirements.

A comparison between the TEDI values shows that the passive house outperforms ASHRAE 90.1 budget by 69%. This remarkably lower TEDI demonstrates a significant reduction of heat loss through building envelope and heat demand required by ventilation system. Based on thermal resistivity calculations tabulated in Table A-1 of Appendix A, the overall thermal resistivity of passive house's external walls is 316% higher than the ASHRAE 90.1-2010 budget building. The passive house's roof has 143%, floor has 152%, and windows have 152% higher thermal resistivity than the budget building. The budget building features minimum thermal performance requirements of envelope assemblies based on "Prescriptive Compliance Path" of ASHRAE 90.1-2010 for climate zone 5. It should also be noted that the passive house is equipped with a central heat recovery ventilator (HRV) of 82% sensible recovery effectiveness that plays another key role in reduction of TEDI compared to the budget building with no HRV.

The effect of 69% lower TEDI in the passive design is reflected in a lower space heating energy (see Table 2) that shows a 72% reduction compared to the budget building. A minor portion (~3% from 72%) of the heating energy reduction from budget to passive design is related to a higher coefficient of performance (COP) of the selected heat pump for the passive house compared to the minimum COP of heat pump required by ASHRAE 90.1-2010 for the budget building. It can be concluded that the effect of HVAC efficiency improvement on total energy reduction of a building becomes insignificant at a passive-house-level design with high performance envelope system.

To further investigate this conclusion, Table 3 and Figure 3 compare energy consumption of the passive house equipped with 1) existing heat pump (COP 3.8), and 2) electric baseboard heater (COP 1.0 or efficiency 100%). The second heating system design is one of the most commonly used systems in the Canadian building industry. In addition, Table 4 and Figure 4 provide a same comparison for the budget building as a representative of ASHRAE-level design to evaluate the effect of HVAC efficiency on energy consumption and to compare with the passive-house-level design results.

Table 4: Comparison Between Passive House-Heat Pump & Passive House-Electric Baseboard Heater

Model	Heating Energy [kWh/m^2/y]	Cooling Energy [kWh/m^2/y]	Auxiliary [kWh/m^2/y]	TEUI [kWh/m^2/y]	Unmet Heating Hours [h/y]	Unmet Cooling Hours [h/y]
Passive House - Heat Pump	4.86	3.33	11.86	41.07	54	124
Passive House - Electric Baseboard Heater	10.77	0.0	9.41	41.21	155	423

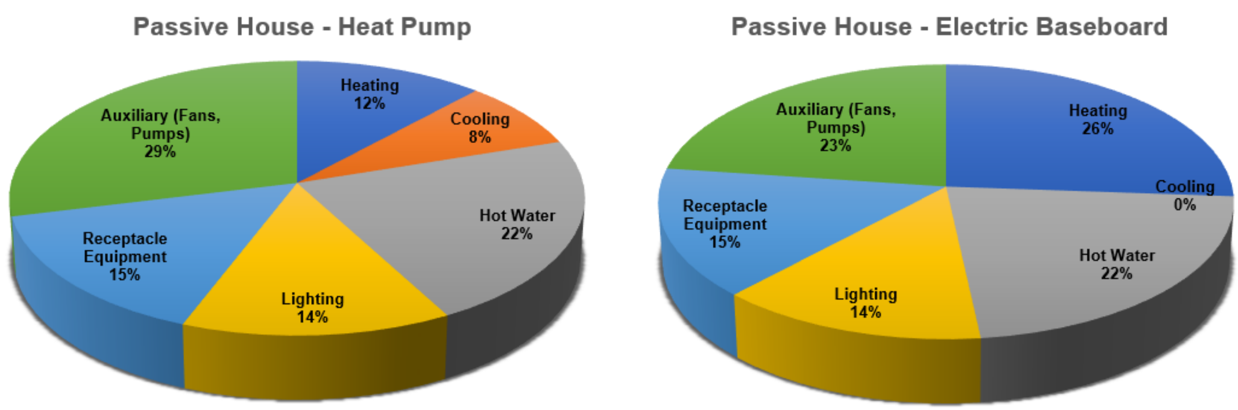

Figure 3: Comparison of Energy Components, Passive House with Heat Pump vs. Electric Baseboard

Table 5: Comparison Between ASHRAE Budget-Heat Pump & Passive House-Electric Baseboard Heater

Model	Heating Energy [kWh/m^2/y]	Cooling Energy [kWh/m^2/y]	Auxiliary [kWh/m^2/y]	TEUI [kWh/m^2/y]	Unmet Heating Hours [h/y]	Unmet Cooling Hours [h/y]
ASHRAE Budget - Heat Pump	17.53	3.75	12.45	78.69	47	108
ASHRAE Budget - Electric Baseboard Heater	52.8	0.0	9.40	107.16	184	391

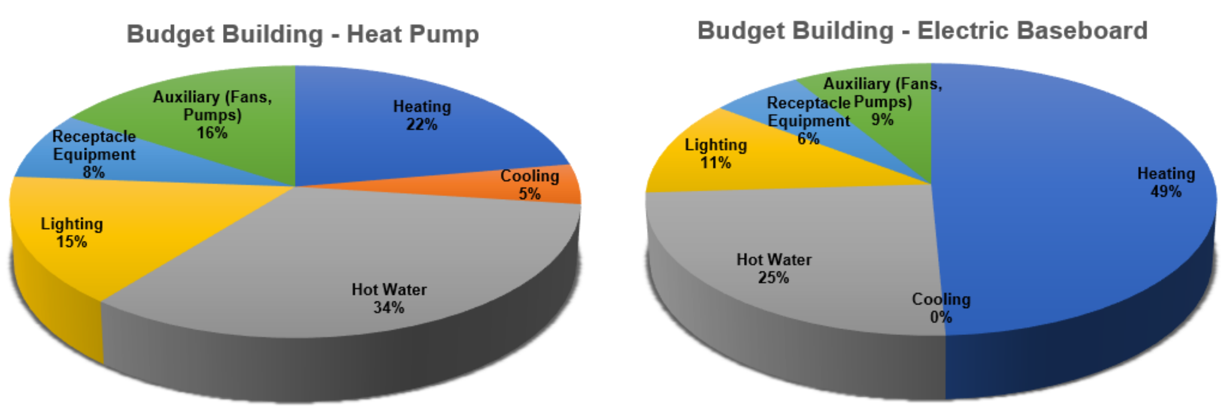

Figure 4: Comparison of Energy Components, ASHRAE Budget with Heat Pump vs. Electric Baseboard

The results from Table 3 and Figure 3 show that the total energy consumption of the passive house equipped with heat pump is only 0.3% less than the passive house equipped with electric baseboard heaters and no cooling system. The results indicate that despite 55% reduction of heating energy component from electric baseboard to heat pump in the passive house, the overall energy consumption changes negligibly due to elimination of cooling energy and heat pump fan energy in the electric baseboard design. However, a same comparison for ASHRAE-level building design from Table 4 and Figure 4 shows that the heating energy decreases by 67% from baseboard to heat pump, which along with elimination of cooling and heat pump fan energy consumptions lead to 27% reduction in the overall energy consumption. Accordingly, one can conclude that the importance and weight of type and efficiency of HVAC system on the total energy consumption of a building fades as the building envelope characteristics moves from the ASHRAE-level design towards the high-performance passive-house-level design.

A key factor of appropriate HVAC design in any type of building is the number of unmet hours that represents the total yearly hours that the conditioned spaces in a building undergo thermal discomfort. Based on ASHRAE 90.1-2010 Standard, the total yearly unmet hours shall not exceed 300. However, the results from tables 3-4 show that for the electric baseboard heater case, the unmet hours exceed the standard requirement and cannot be acceptable. Therefore, downgrading from heat pump to electric baseboard heater is not appropriate from the unmet cooling hours perspective.

A considerable aspect of passive house design is utilization of appropriate external shading. Winter solar heat gain plays an important role in reducing heating demand of a passive house; however, summer solar heat gain can cause overheating of perimeter spaces in a passive house and increase the cooling energy demand. To evaluate the effect of designed external shading on energy consumption of the studied passive house, an energy model is executed with all shades removed.

Table 5 and Figure 5 show comparisons between the energy components of the passive building with and without external shadings. The comparison shows that the solar heat gain enhancement after external shading removal decreases the space heating energy consumption by 29%; however, increases the cooling energy consumption by 65% and the total energy consumption by 3%. Therefore, the external shading has constructive effects on total energy saving of the passive house design. It can be expected that the appropriate external shading plays a more significant role in reduction of cooling, and thus, the total energy consumption in warmer climate conditions (i.e. ASHRAE Climate Zones 1-4). It should be noted that the modelling results show that the effects of external shading on lighting energy consumption is negligible in this building due to appropriate external shading depth, low glazing ratio, and low lighting power density.

Table 6: Energy Consumption Breakdown [kWh/m^2/y]; Passive House with & without External Shades

Model	Heating	Cooling	Service Hot Water	Lighting	Receptacle/ Equipment	Auxiliary (Fans, Pumps)	TEDI	TEUI
Passive House with External Shades	4.86	3.33	9.13	5.62	6.28	11.86	15.58	41.07
Passive House without External Shades	3.47	5.49	9.13	5.62	6.28	11.86	14.32	42.12

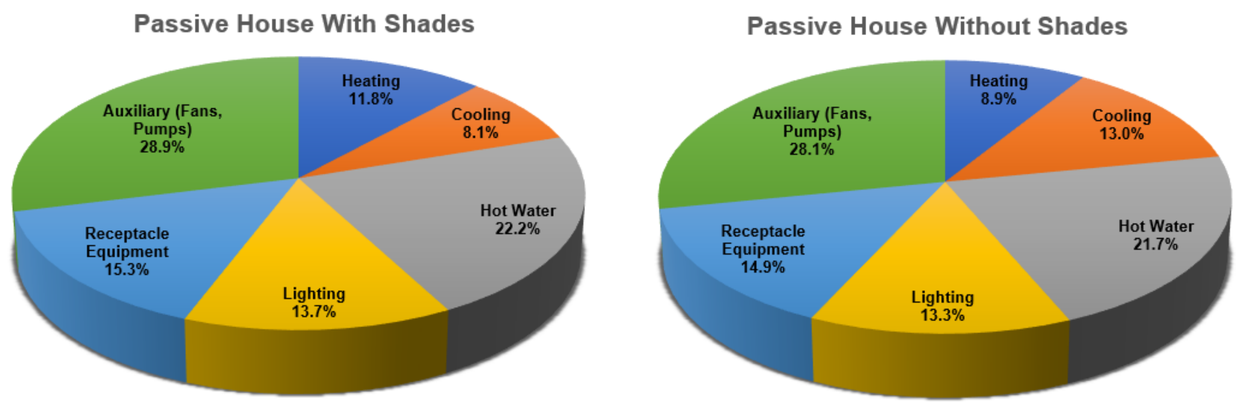

Figure 5: Comparison of Energy Components, Passive House with and without External Shades

Passive House Planning Package (PHPP) is an excel-sheet-based software tool utilized internationally for energy modelling and certification of passive houses (http://passiv.de/en/04_phpp/04_phpp.htm). PHPP calculates heating and cooling energy demands based on degree-hours method considering a monthly averaged outdoor temperature and the effects of solar radiance. PHPP is a powerful tool for energy estimation and breakdown of passive houses; however, the method of calculating heating and cooling demands is not as accurate as an hourly simulating software tool that considers a variety of important factors, including the effects of thermal mass, hour-by-hour variations of outdoor and indoor conditions, transient hourly solar heat gain by envelope components, realistic operation of HVAC systems at full and part loads and its impacts on transient thermal condition and energy consumption, among others. Therefore, the accuracy of PHPP is not expected to be as high as the accuracy of a validated hourly energy analysis program required by ASHRAE 90.1-2010, Chapter 11. However, our literature review shows that there is no comprehensive study comparing the accuracy of PHPP with an hourly energy analysis program for a real passive house.

To evaluate the difference between energy modelling results of IES-VE 2017 and PHPP tool, a model of the passive building is created in PHPP based on the inputs provided in Table A-1. A comparison between PHPP V9.3 and IES-VE 2017 results for the modelled passive house daycare is provided in Table 6 and Figure 6.

Table 7: Energy Consumption Breakdown of Passive House [kWh/m^2/y]; IES-VE 2017 vs. PHPP V. 9.3

Model	Heating	Cooling	Service Hot Water	Lighting	Receptacle Equipment	Auxiliary (Fans, Pumps)	TEDI	Total (TEUI)
IES-VE 2017	4.86	3.33	9.13	5.62	6.28	11.86	15.58	41.07
PHPP V. 9.3	6.57	0.02	11.48	5.62	6.28	12.05	14.33	42.02

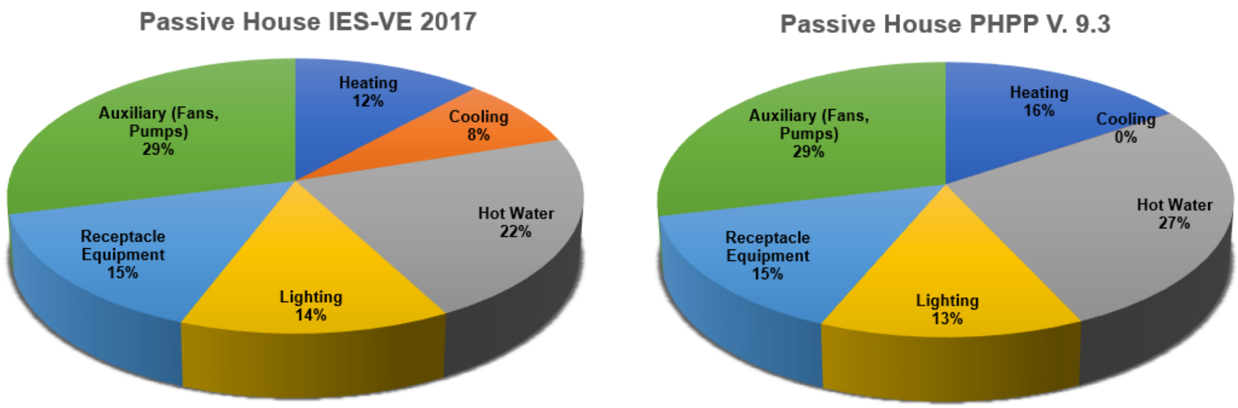

Figure 6: Comparison of Passive House Energy Components Between IES-VE 2017 and PHPP V. 9.3

A comparison between the IES-VE and PHPP results shows that there are only 8% and 2% differences between the two model calculations of TEDI and TEUI, respectively. However, the differences of heating, cooling, and service water heating components from the two models are considerable. More specifically, the heating energy calculated by PHPP is 35% larger than IES-VE, whereas the heating demand (TEDI) is 8% smaller. Further, the hot water energy calculated by PHPP is 26% larger than IES-VE, whereas the hot water consumption is assumed equal in the two models. Our investigation into the details of PHPP calculations shows that a seasonally-averaged coefficient of performance (COP) is considered in this software and applied on the total corresponding heat demands rather than an hourly calculation and consideration of the real nature of heat pump operation under transient ambient condition. On the other side, IES-VE simulates the operation of modelled heat pumps more realistically under transient conditions. In addition, PHPP calculates the number of indoor overheated hours on a simple monthly-averaged temperature and humidity basis rather than hour-by-hour simulation, which leads to significantly lower cooling demand prediction. Based on the IES-VE modelling results, the passive house will undergo more than 400 unmet hours (overheated indoor temperature > 75±2ºF) with PHPP assumptions on cooling demand calculations

11 CONCLUSIONS

This paper focused on comparison of energy metrics of a non-residential passive house with its corresponding ASHRAE 90.1-2010 budget building. Canada's first non-residential passive house with daycare application was modelled in IES-VE 2017 and PHPP V9.3. The results showed that the passive house had 69% lower TEDI (i.e. thermal energy demand intensity) and consumed 48% less total energy than its corresponding ASHRAE 90.1-2010 budget building. Building envelope components with higher thermal performance, and utilization of high efficiency heat recovery ventilator played key roles in TEDI reduction of the passive house in comparison to the budget building. In addition to a lower TEDI, utilization of high efficiency heat pump for domestic water heating and a high efficiency lighting system in the passive house design led to a remarkably lower TEUI (i.e. total energy use intensity) of the passive house compared to the budget building.

A comparison between heat pump and electric baseboard heater systems for both passive house and its corresponding budget building showed that the importance of HVAC efficiency on the total energy consumption of a building reduces as the building envelope characteristics change from the ASHRAE-level design towards the high-performance passive-house-level design.

The effect of external shading on energy consumption of the passive house was also studied and the results showed that an appropriate external shading has constructive impacts on total energy saving of a passive house design.

Modelling results of the passive house in the hourly analysis program IES-VE 2017 was compared to the results from the most commonly used software for passive house design and certification, PHPP V9.3. It was shown that there are 8% and 2% differences between the two model calculations of TEDI and TEUI, respectively. However, larger differences exist between the breakdown of energy components, and thermal comfort consideration in IES-VE 2017 and PHPP V9.3.

REFERENCES

ANSI/ASHRAE/IES (2010) ANSI/ASHRAE/IES Standard 90.1-2010 Standard for Buildings Except Low-Rise Residential Buildings.

City of Vancouver (2009) Passive Design Toolkit for Homes.

Dumont R.S., et al. (1978) Passive Solar Heating – Results from Two Saskatchewan Residences, 4th Annual Conference of the Solar Energy Society of Canada, Inc., London, Ontario.

Energy Step Code Council (2017) BC Energy Step Code – A Best Practices Guide for Local Governments, V1.2.

Environment and Climate Change Canada (2018) Canadian Environmental Sustainability Indicators Greenhouse Gas Emissions.

Natural Resources Canada (2016) Energy Efficiency Trends in Canada.

Nisson J.D.N., Dutt G. (1985) The Superinsulated Home Book, John Wiley & Sons.

Orr H., et al. (2013) Airtightness of older-generation energy-efficient houses in Saskatoon, Journal of Building Physics, 36 (3).

Sadineni S.B., et al. (2011) Passive Building Energy Savings: A Review of Building Envelope Components, Renewable and Sustainable Energy Reviews, 15 (8) 3617-3631, 2011.

Shaviv E. (2008) Passive and Low Energy Architecture (PLEA) VS Green Architecture (LEED), 25th Conference on Passive and Low Energy Architecture, Dublin.

Shurcliff W.A. (1986) Superinsulated Houses, Annual Review of Energy, (11) 1-24, 1986.

Stecher D., Klingenberg K. (2008) Design and Performance of the Smith House – A Passive House, ASHRAE Conference Proceedings NY-08-027, New York.

Wright G.S., Klingenberg K. (2015) Climate-Specific Passive Building Standards, U.S. Department of Energy.

Web sites:

Web-1: http://passiv.de/en/04_phpp/04_phpp.htm, visited 27 June 2018.

APPENDIX A: DETAILED MODEL INPUTS

Table A-1: Model Inputs for Passive House Design and ASHRAE 90.1 Budget Building

Item	Budget Building Design (ASHRAE 90.1-2010)	Passive House Design
1. Building and Location		
Location	Penticton, BC	
Simulation Weather File	Summerland_BC_CWEC.fwt	
Climate Zone	ASHRAE Climate Zone 5	
Modeling Software	IES-VE 2017	
Floor Area [m^2]	375	
Building Type	Non-Residential (Daycare Usage), Wood-Framed	
2. Design Conditions		
Indoor Design Condition	Cooling: 75ºF (±2ºF), 50% RH Heating: 70ºF (±2ºF)	
3. Building Envelope		
Roof Overall Thermal Resistivity [$m^2.K.W^{-1}$]	(R-37.04 IP); ASHRAE 90.1-2010 Table 5.5-5	15.85 (R-90 IP)
Above Grade Wall Overall Thermal Resistivity [$m^2.K.W^{-1}$]	2.75 (R-15.63 IP); ASHRAE 90.1-2010 Table 5.5-5	11.45 (R-65 IP)
Slab-On-Grade Floor Perimeter Heat Loss Factor [$W.m^{-1}.K^{-1}$]	0.04 (F-0.73 IP); ASHRAE 90.1-2010 Table 5.5-5	0.02 (F-0.29 IP)
Vertical Glazing Overall Thermal Resistivity [$m^2.K.W^{-1}$]; Solar Heat Gain Coefficient	0.50 (U-0.35 IP); SHGC-0.40; ASHRAE 90.1-2010 Table 5.5-5	1.26 (U-0.14 IP); SHGC-0.52
Shading	No Shading	Exterior Overhang Shading
Glazing Percentage	26%	
Infiltration	0.1 [L/s/m^2facade] at operating pressure	

4. Internal Loads		
Occupancy	47 Occupants; Schedule: ASHRAE 90.1-2010 User's Manual, Appendix G	
Interior Lighting Power Density [W/m^2]	Overall (Area-Averaged): 11.20	Overall (Area-Averaged): 5.19
Interior Lighting Controls and Schedule	Lighting Controls as per ASHRAE 90.1-2010 Section 9.4.1; Schedule: ASHRAE 90.1-2010 User's Manual, Appendix G	
Receptacle/Appliance	Total Installed Power: 7,650 [W] Schedule: ASHRAE 90.1-2010 User's Manual, Appendix G	
5. HVAC Systems		
Heating and Cooling	ASHRAE 90.1-2010 System 9: Packaged Rooftop Heat Pump, ASHRAE 90.1-2010 Section 6.8 Efficiencies	Variable Refrigerant Flow Air Source Heat Pump, COP 3.8 (AHRI)
Ventilation	ASHRAE 62.1-2010, Direct to Heat Pump Terminals with Exhaust from Bathrooms (No HRV)	ASHRAE 62.1-2010, Central Heat Recovery Ventilator (HRV), 82% SRE
Domestic Hot Water	Electric Water Heater, Efficiency from ASHRAE 90.1-2010 Table 7.8	Hybrid Electric Water Heater with Energy Factor 3.50