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# Assessing Airtightness Metrics for New Housing Building Code Compliance

Analysis of PCF 1819

Author(s): Adam D. Wills, Iain Macdonald  
Report No.: A1-013150.26  
Report Date: 09 September 2024  
Contract No.: A1-023465  
Agreement Date: 01 April 2017



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# Assessing Airtightness Metrics for New Housing Building Code Compliance

## Analysis of PCF 1819

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Adam D. Wills, Ph.D.

Approved

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## Executive Summary

Proposed Change Form (PCF) 1819 was submitted to public review during the 2020-2025 National Building Code (NBC) of Canada development cycle. The PCF proposed alterations to the way in which airtightness performance is defined and credited in the prescriptive and performance paths of Section 9.36 of the NBC. Under the Tiered Prescriptive Path of Subsection 9.36.8, energy conservation points may be awarded for testing and achieving airtightness “levels” defined in Subsection 9.36.6. Currently, a level is defined using airchanges per hour @  $\Delta P=50$  Pa ( $ACH_{50}$ ), normalized leakage rate @  $\Delta P=50$  Pa ( $NLR_{50}$ ), and normalized leakage area @  $\Delta P=10$  Pa ( $NLA_{10}$ ). PCF 1819 proposes to remove  $ACH_{50}$  from the level definitions in Subsection 9.36.6., and only express airtightness performance in terms of envelope area-normalized metrics. In the performance path PCF 1819 proposed to define reference building airtightness performance in terms of  $NLR_{50}$  instead of  $ACH_{50}$ . The PCF also proposes to use different reference airtightness performances between attached and detached homes where currently no such distinction exists; under 2020 NBC a lower airtightness performance (3.0 instead of 2.5  $ACH_{50}$ ) is only used if the proposed building is attached and its airtightness is tested using the unguarded approach. Finally, PCF 1819 proposes to allow reference and proposed building models to assume the same airtightness performance in the Tiered Performance Path if no airtightness testing is done and the air barrier is constructed per Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10. The 2020 NBC requires the proposed building assume a performance of 3.2  $ACH_{50}$  and reference 2.5  $ACH_{50}$  if no airtightness testing is done.

Using the 240 new construction archetypes developed by Asaee & Ferguson (2019), the impacts PCF 1819 will have on prescriptive and performance compliance outcomes were evaluated. It was found that in the prescriptive path most attached and small detached buildings are unaffected by the proposed changes; they currently utilize  $NLR_{50}$  to define their airtightness levels. Larger detached buildings, however, were found to mostly use  $ACH_{50}$  to determine their airtightness levels, and with the removal of  $ACH_{50}$  would need to achieve higher airtightness performance to meet a given level than what is currently required.

The impact of PCF 1819 on the performance path was found to vary based on several factors: building geometry and attachment type, whether airtightness testing is being used for compliance, type of airtightness test (guarded or unguarded), and whether the base (Subsection 9.36.5.) or Tiered (Subsection 9.36.7.) performance paths were being utilized. The general observations were that if no airtightness testing is done as a measure for compliance there is minimal impact to compliance outcomes under Subsection 9.36.5., and a relaxation of requirements in Subsection 9.36.7. The latter is primarily due to PCF 1819 removing the airtightness performance gap if airtightness testing is not done. For cases where airtightness testing is used for compliance, the impacts of the PCF are shown to vary with attachment type and surface-to-volume ratio. Larger detached homes, which tended to have smaller surface-to-volume ratios in the archetype set, have an increase in reference building airtightness performance compared to current code. Subsequently, they must increase their airtightness and/or implement additional conservation measures to maintain compliance. Attached and smaller detached homes generally experience a reduction in reference building airtightness performance, and subsequently can use a reduced airtightness performance and/or implement fewer energy conservation measures while maintaining compliance.

A case study using Tier 3 and Climate Zone 7A was used to further investigate the impacts of PCF 1819. Using the 240 archetypes, two sets of Tier 3 compliant solutions were developed: 2020 NBC and PCF 1819 compliant. In both sets, compliance was achieved using the performance path and measured airtightness. The results found that 63.7% of the archetypes have higher annual space heating loads under PCF 1819 compared to 2020 NBC. Generally, homes with conditioned volumes above 600 m<sup>3</sup> see a savings in annual space heating load under PCF 1819, whereas those below 600 m<sup>3</sup> experience an increase in annual space heating. It was noted that these general observations are applicable to all tiers and climates for cases where the performance path and airtightness testing are used for compliance.

# 1 Introduction

Proposed Change Form (PCF) 1819, titled “Removing ACH<sub>50</sub> and Harmonizing Airtightness Requirements in Section 9.36.”, was submitted to public review for inclusion in the 2025 edition of the National Building Code of Canada (NBC). The proposed changes include removing airchanges at  $\Delta P=50$  Pa (ACH<sub>50</sub>) [h<sup>-1</sup>] as an optional metric to determine building airtightness level as defined in Article 9.36.6.4 of the 2020 NBC (CCBFC, 2020), and to replace ACH<sub>50</sub> with normalized leakage rate at  $\Delta P=50$  Pa (NLR<sub>50</sub>) [L/(s·m<sup>2</sup>)] as the metric used to specify airtightness in the performance compliance path described in Subsections 9.36.5. and 9.36.7. of the 2020 NBC. The stated objectives and justifications of the PCF are to align airtightness performance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10. of the 2020 NBC, simplify airtightness metrics, and align the performance path as described in Subsection 9.36.5. with the tiered performance path in 9.36.7.

This report describes analyses conducted to assess the functional impacts of the proposed changes in PCF 1819 on compliance outcomes and energy performance. Section 2 provides foundational information on building and systems energy efficiency requirements contained in the 2020 NBC, description of the airtightness testing procedure for code compliance, a review of airtightness performance metrics, how infiltration is modelled for performance path compliance calculations, and a summary of the proposed changes in PCF 1819. Section 3 describes the calculation approaches and building archetypes used to assess the impact of PCF 1819. Section 4 provides the results of the analyses, and Sections 5 and 6 provide discussions and conclusions of the analyses.

## 2 Background

### 2.1 Summary of Section 9.36 of the 2020 NBC

Part 9 buildings, as defined in Sentence 1.3.3.3.(1) of the 2020 NBC, are buildings with a footprint area not exceeding 600 m<sup>2</sup> and having three storeys or less, with major occupancies classified as Group B, Division 4, Groups C to E, and Group F, Division F. Typically, Part 9 is applied to low and mid-rise residential buildings (Group C). The minimum energy efficiency requirements of Part 9 are provided in Section 9.36 of the 2020 NBC. In summary, a builder can demonstrate compliance using two pathways: prescriptive or performance. Under the prescriptive path, the building envelope, heating, ventilation and air conditioning (HVAC) equipment, and service hot water systems must meet the minimum performance specifications described in Subsections 9.36.2., 9.36.3., and 9.36.4., respectively. Alternatively, Subsection 9.36.5. describes the performance compliance path which relies on detailed annual energy performance calculations to demonstrate that a proposed building consumes no more annual energy for end-uses under the scope of the code (i.e., space conditioning, service hot water, and ventilation) compared to a code-defined reference building which has the same shape and size as the proposed building, but its components (envelope and equipment) are all assumed to be prescriptive code-minimum. Unlike the prescriptive path, Sentence 9.36.1.3.(3) states that the performance path only applies to residential buildings.

The airtightness performance of the code-reference building under the performance path in Subsection 9.36.5. is provided in Clauses 9.36.5.14.(2)(d) and (e). In summary, if an “unguarded” test, described later in Section 2.2, is performed for an attached building, then the reference building is modelled with an airtightness performance of 3.0 airchanges per hour (ACH) at a  $\Delta P=50$  Pa (ACH<sub>50</sub>). Otherwise, if the building is detached, attached and a guarded test was performed, or attached but no airtightness test is conducted, a reference airtightness performance of 2.5 ACH<sub>50</sub> is used.

Airtightness performance used in the proposed building model is described in Sentence 9.36.5.10.(9):

1. Clause (a): 3.2 ACH<sub>50</sub>, or
2. Clause (b): 2.5 ACH<sub>50</sub> if the air barrier was constructed in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., or
3. Clause (c): The measured performance.

The 2020 edition of the NBC introduced the Tiered compliance system which built upon the pre-existing prescriptive and performance compliance pathways. In both pathways five tiers were defined, with each increasing tier corresponding to increasing performance requirements relative to code minimum. The Tiered prescriptive path, described in Subsection 9.36.8., utilizes a points-based compliance system. The builder is still obligated to adhere to the minimum prescriptive performance requirements defined in Subsections 9.36.2 to 9.36.4, but must also select additional energy conservation measures provided in the tables in Subsection 9.36.8. Each measure is allocated an amount of energy conservation points (ECPs), and the sum of ECPs across all selected measures must meet the minimum amount described in Table 9.36.8.2. for the corresponding Tier. Table 9.36.8.8. provides the ECPs for airtightness performance. Airtightness performance and corresponding points are defined using an airtightness level, which are defined in Tables 9.36.6.4.-A and B. Each airtightness level is defined using three metrics: ACH<sub>50</sub>, NLR<sub>50</sub>, and normalized leakage area at  $\Delta P=10$  Pa (NLA<sub>10</sub>). Sentence 9.36.6.4.(1) states that either one of the metrics may be used to determine airtightness level.

The Tiered performance path described in Subsection 9.36.7. builds off of Subsection 9.36.5. with some caveats. Table 9.36.7.2. provides the compliance criteria for Tiers 1 to 5, and uses three metrics to determine compliance: 1) percent heat loss reduction, 2) percent improvement, and 3) relative peak cooling load. All three metrics are determined by comparing detailed annual energy calculations of the proposed building relative to a code-defined reference. Article 9.36.7.3. provides the calculations procedures, and Sentence (1) states that the procedure is to follow those described in Subsection 9.36.5. The following is a summary of the deviations to the calculation procedure implemented in Subsection 9.36.7. relative to Subsection 9.36.5.:

- Sentence 9.36.7.3.(3): for Tiers 2 to 5 if the proposed building uses a heat pump for space heating, then the reference shall use a reference system that has the same fuel type as the back-up system in the proposed building. If there is no back-up system, then an electric resistance heating system is used in the reference. This deviates from Subsection 9.36.5., where according to Sentence 9.36.5.15.(2) if a heat pump space heating system is used in the proposed building, then a code-minimum heat pump is used in the reference model. To maintain alignment, Tier 1 calculations do not implement the exception provided in Sentence 9.36.7.3.(3).
- Sentence 9.36.7.3.(4): If there are no cooling systems installed, an additional reference and proposed model are to be generated with appropriately sized cooling systems to determine peak cooling load.
- Sentence 9.36.7.3.(9): If no airtightness test is performed then the value set out in Clause 9.36.5.10.(9)(a) is to be used (i.e., 3.2 ACH<sub>50</sub>), otherwise the measured value may be used.

Unlike like the performance path in Subsection 9.36.5., the Tiered Performance Path only permits the use of 3.2 ACH<sub>50</sub> in the proposed building model if no airtightness test is done. Shown previously, Clause 9.36.5.10.(9)(b) allows a proposed building airtightness of 2.5 ACH<sub>50</sub> if the air barrier was constructed in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10. when the Subsection 9.36.5. performance path is used.

## 2.2 Airtightness Testing

Building envelope airtightness measurement for code compliance is described in Article 9.36.6.3. of the 2020 NBC which references CAN/CGSB Standard 149.10-2019 (CGSB, 2019). The standard uses a fan-pressurization/depressurization technique to measure the in-situ airtightness performance of a building envelope which requires installing a calibrated fan in an opening of the building envelope, typically a doorway. The fan is used to induce a pressure difference between the interior and exterior of the building ( $\Delta P$ ), and once the measured pressure differential has stabilized at the desired value, the volumetric flow rate is measured through the fan. Flow is assumed to be incompressible, and therefore, the mass flow rate through the fan is assumed to be equal to mass flow rate infiltrating (or exfiltrating if the building is pressurized). The volumetric flow rate infiltrating into the envelope during a depressurization test, corrected to standard conditions,  $Q_r$  [L/s], is calculated using Equation (1) (CGSB, 2019):

$$Q_r = Q_m \cdot \sqrt{\frac{T_o + 273}{T_i + 273}} \quad (1)$$

where  $Q_m$  is the indicated volumetric flow rate [L/s] measured across the fan which has not been corrected for differences between indoor air drybulb temperature during the test,  $T_i$  [°C], and the temperature the fan was calibrated at,  $T_c$  [°C], and  $T_o$  [°C] is the outdoor drybulb temperature measured during the test. It is important to note that Equation (1) only holds true if the fan was calibrated at the standard temperature of 20 °C and standard pressure of 101.325 kPa which are the standard conditions used in CAN/CGSB 149.10-2019. Further details on calculating  $Q_r$  may be found in Annex A of the standard (CGSB, 2019).

In a multi-point test a minimum of six values of  $Q_r$  are measured at different pressure differentials,  $\Delta P$  [Pa], across the envelope. Both before and after the airtightness test is performed, a time-averaged value of  $\Delta P$  under no-flow conditions are measured, and the average value of the two no-flow  $\Delta P$  values are subtracted each  $\Delta P$  value measured during the test to yield a “corrected”  $\Delta P$  ( $\Delta P_r$ ). The  $Q_r$  and  $\Delta P_r$  data pairs are then fit to a power law:

$$Q_r = C_r \cdot \Delta P_r^n \quad (2)$$

where  $C_r$  is the flow coefficient [L/(s·Pa<sup>n</sup>)], and  $n$  is the flow exponent [dimensionless]. The valid range of flow exponents is between 0.5, which indicates fully turbulent flow, and 1, which indicates fully laminar flow. CAN/CGSB 149.10-2019 does permit a single point test at  $\Delta P=50$  Pa. Since more than one data point is required to determine  $C_r$  and  $n$ , the standard assumes a value of  $n$  equal to 0.68 for single-point tests, and then  $C_r$  is calculated from the test data.

Building preparation prior to conducting the test is also described in the standard. Two assessment types are described in Section 6.1.4 of the standard: “closed-up” and “as-operated”. Clause 9.36.6.3.(2)(a) in the 2020 NBC requires that the building be tested in the “as-operated” condition for the purposes of measurement for code compliance. This differs from the 2015 version of the code which referenced the 1986 version of the CGSB standard (CGSB, 1986) which only had the “closed-up” configuration. In the “as-operated” configuration, all windows and dampers are closed, but other intentional envelope penetrations, such as flues, are left unsealed. Therefore, the infiltration measured during the test includes leakage through both intentional and unintentional openings. Further details are omitted for clarity, and the interested reader is directed to Table 3 in the 2019 standard for additional information.

Clause 9.36.6.3.(2)(b) in the 2020 NBC states that either a “guarded” or “unguarded” test may be used to measure airtightness for code compliance. Unguarded testing only applies to spaces that are attached to other spaces; for example, a mid-row residential building which is attached on two sides to other dwelling units. In an unguarded test, a single fan depressurization device is installed in an opening of a space to be tested, and the measured infiltration during the test is a combination of infiltration through the exterior-facing envelope of the space, and leakage across the partitions separating the tested unit and adjacent units. A guarded test uses

additional fan depressurization units installed in envelope openings of all adjacent units to the unit being tested. All fans are simultaneously controlled such that the pressure differential across the partitions is approximately zero when the desired  $\Delta P$  is achieved across the exterior envelope of the test unit. Both unguarded and guarded test setups are illustrated in Figure 1.

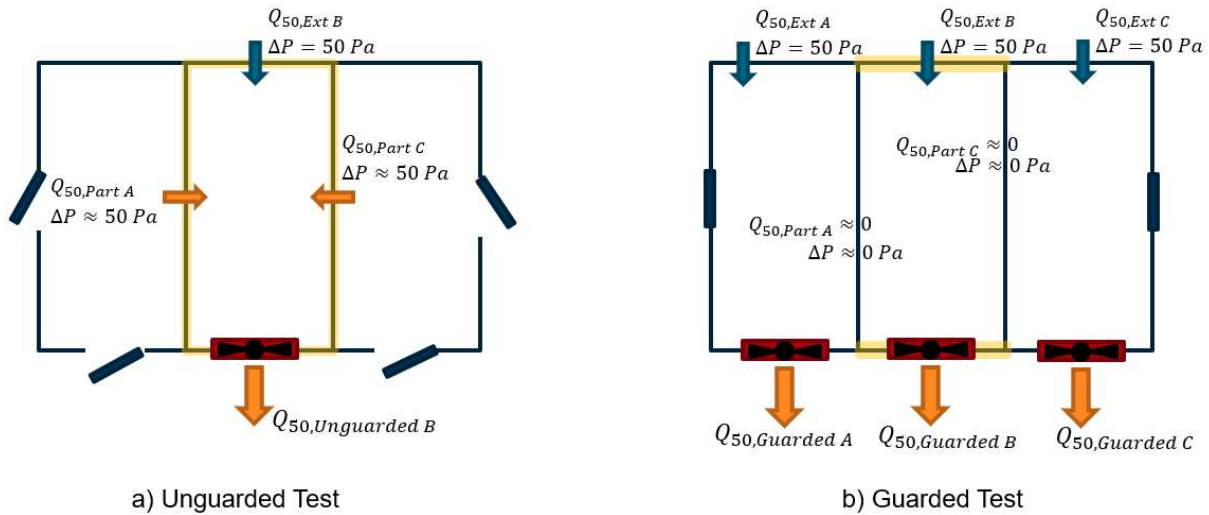


Figure 1. Unguarded and guarded test setup

Inducing a zero-pressure gradient across the partitions inhibits flow across those surfaces, and therefore, the flow rate measured at the fan installed in the test unit nominally represents infiltration rate across the exterior surfaces only. This is typically the desired measurement as the performance of the exterior air barrier is the metric that impacts energy performance. It is also important to note in Figure 1 that for unguarded testing, the exterior windows and doors of the adjacent units *must be* open, as required per Section 6.1.8 of the standard. This is done to equalize the pressure between outside and the interior of the adjacent units, and therefore, equalize the pressure difference across all bounding surfaces of the test space.

In practical terms, all tests of detached units are “guarded” since the measured flow rate is only flow across exterior surfaces and surfaces separating conditioned from unconditioned spaces (e.g., and attached garage).

## 2.3 Airtightness Metrics

Sherman & Chan (2004) state that there are three commonly used quantities to normalize building infiltration flow: volume, envelope area, and floor area. They note that each normalizing quantity has its advantages and disadvantages:

- Volume-normalized airtightness such as  $ACH_{50}$  is likely the most commonly reported airtightness performance metric, and is therefore convenient and has the same units (airchanges per hour) as minimum ventilation rate requirements in some standards (e.g., CAN/CSA-F326-M91(R2005))
- Envelope area is “particularly useful if one is looking to define the quality of the envelope as a uniform ‘fabric’” (Sherman & Chan, 2004). It effectively expresses the nominal porosity of the entire envelope.
- Floor area is usually more readily available and is therefore a convenient metric.

Historically, airtightness of Canadian homes has been reported in  $ACH_{50}$ . This is likely a legacy of voluntary standards such as R-2000, which as far back as 1986 used  $1.5 ACH_{50}$  (or  $NLA_{10}$  of  $0.7 \text{ cm}^2/\text{m}^2$ ) as an airtightness performance target for compliance (CHBA/EMR, 1986). Since then, other voluntary programs such as ENERGY

STAR® (NRCan, 2017) and Passivhaus (PHI, 2024) have also used  $ACH_{50}$  to set airtightness compliance targets. Per CAN/CGSB 149.10-2019,  $ACH_{50}$  is calculated using Equation (3):

$$ACH_{50} = \frac{3.6 \cdot C_r \cdot 50^n}{V} \quad (3)$$

where  $V$  is the “interior” volume of the building [ $m^3$ ], and  $C_r$  and  $n$  are the flow coefficient and exponent, respectively, that were described previously in Section 2.2. The volume is measured per Section 7.2.1 of the CAN/CGSB standard (CGSB, 2019) which includes all rooms and spaces enclosed by the envelope, as well as the volume of interior partitions and spaces between floors. The constant 3.6 is a unit conversion scalar with units  $[(s \cdot m^3)/(h \cdot L)]$ .

Per CAN/CGSB 149.10-2019,  $NLR_{50}$  is calculated using Equation (4):

$$NLR_{50} = \frac{C_r \cdot 50^n}{A} \quad (4)$$

where  $A$  is the building envelope area [ $m^2$ ]. The building envelope area includes “all portions of the envelope, including areas above and below grade. Portions of the building envelope include ceilings, floors, walls, windows, and doors” (CGSB, 2019). For guarded tests, only the “exposed area”,  $A_e$ , of the envelope is used for area in Equation (4); i.e., surfaces separating the test unit from attached units and conditioned spaces are excluded. For unguarded tests the total area,  $A_T$ , including partition surfaces, are used for the area in Equation (4). Further details on determination of the normalizing area may be found in Section 7.1 of the CAN/CGSB standard.

Per CAN/CGSB 149.10-2019,  $NLA_{10}$  [ $cm^2/m^2$ ] is calculated using Equation (5):

$$NLA_{10} = \frac{11.57 \cdot \sqrt{\rho_r} \cdot C_r \cdot 10^{n-0.5}}{A} \quad (5)$$

where  $\rho_r$  is the density of air at standard 20 °C and 101.325 kPa conditions [ $1.204 \text{ kg}/m^3$ ]. The constant 11.57 arises from an assumed discharge coefficient,  $C_D$ , of 0.611. Either  $A_e$  or  $A_T$  is used in Equation (5) depending on the test performed. Further details on the derivation of Equation (5) may be found in Wills & Macdonald (2018).

Stated previously in Section 2.1 of this report, Tables 9.36.6.4.-A and B of the 2020 NBC define airtightness levels for prescriptive code compliance, where the airtightness level may be determined using  $ACH_{50}$ ,  $NLR_{50}$ , or  $NLA_{10}$ . This flexible approach was adapted from ENERGY STAR® (NRCan, 2017) which also allows the user to select the most appropriate metric to determine compliance. Wills, Macdonald, & Knudsen (2020) previously analyzed the metrics and values in Tables 9.36.6.4.-A and B, and noted that there exists no direct conversion between metrics using volume normalization and metrics using area normalization. Rather, the metrics may be related to each other via a ratio of volume-to-area. By combining Equations (3) and (4) in this report the following relationship can be derived:

$$ACH_{50} = 3.6 \cdot \left(\frac{A}{V}\right) \cdot NLR_{50} \quad (6)$$

The value of  $A$  in Equation (6) is either  $A_e$  or  $A_T$  depending on whether the test was guarded or unguarded, respectively. Wills, Macdonald, & Knudsen (2020) used Equation (6) to compare the  $ACH_{50}$  and  $NLR_{50}$  values used to define each airtightness level. They found that for the values in Table 9.36.6.4.-A (guarded or detached buildings), the minimum  $ACH_{50}$  value for a given airtightness level directly computes to the minimum  $NLR_{50}$  specified if  $A_e/V$  is 0.78-0.79  $m^2/m^3$  (varies slightly by level). Using the 120 detached new construction

archetypes from Asaee & Ferguson (2019), Wills, Macdonald, & Knudsen (2020) found the average  $A_e/V$  was  $0.79 \text{ m}^2/\text{m}^3$ ; therefore, on average the archetypes would achieve the same performance compliance outcomes using either  $\text{ACH}_{50}$  or  $\text{NLR}_{50}$ . For the metrics and values in Table 9.36.6.4.-B, they found maximum allowable  $\text{ACH}_{50}$  for a given airtightness level directly computes to the maximum  $\text{NLR}_{50}$  specified if  $A_T/V$  is  $0.71\text{-}0.73 \text{ m}^2/\text{m}^3$ . Unfortunately,  $A_T$  was not known for the 120 attached archetypes from Asaee & Ferguson (2019), only  $A_e$ . Therefore, the  $A_T/V$  ratio of those archetypes could not be directly determined for converting  $\text{NLR}_{50}$  to  $\text{ACH}_{50}$  for unguarded test results. Recently, Natural Resources Canada's Office of Energy Efficiency has developed estimates for  $A_e$  of the attached archetypes which are utilized later in the current report.

If guarded tests are performed on the attached archetypes, then the normalizing area is  $A_e$  per the CAN/CGSB standard. The average  $A_e/V$  of the 120 attached archetypes is  $0.72 \text{ m}^2/\text{m}^3$ . Using the airtightness level definitions in Table 9.36.6.4.-A, which apply to detached homes and guarded test results of attached homes, the attached archetypes will on average more easily comply using  $\text{ACH}_{50}$  rather than  $\text{NLR}_{50}$  when guarded testing is done. To illustrate, consider an attached building which achieves  $1.5 \text{ ACH}_{50}$  as measured from a guarded test. Using Table 9.36.6.4.-A the building achieves level AL-3A. If the  $A_e/V$  of the building is assumed to be  $0.72 \text{ m}^2/\text{m}^3$ , then using Equation (6) in this report the corresponding  $\text{NLR}_{50}$  guarded performance of the building is  $0.58 \text{ L}/(\text{s}\cdot\text{m}^2) @ \Delta\text{P}=50 \text{ Pa}$  which is above the minimum  $0.53 \text{ L}/(\text{s}\cdot\text{m}^2) @ \Delta\text{P}=50 \text{ Pa}$  stated in Table 9.36.6.4.-A for AL-3A. Therefore, in this case, using  $\text{ACH}_{50}$  would yield compliance with the higher airtightness level compared to using  $\text{NLR}_{50}$ .

## 2.4 Modelling Infiltration for Code Compliance

The building performance simulation tool HOT2000 (NRCan, 2017) is typically used to perform the calculations required in the performance paths described in Subsections 9.36.5 and 9.36.7 of the 2020 NBC. Infiltration is modelled in HOT2000 using the Alberta Infiltration Model (AIM-2) (Walker & Wilson, 1990; Bradley & Riley, 1993). AIM-2 is based on the orifice flow power law shown previously in Equation (2) of this report. The following is a summary of model inputs:

- Conditioned volume,
- $\text{ACH}_{50}$ ,
- Equivalent Leakage Area at  $\Delta\text{P}=10 \text{ Pa}$  ( $\text{ELA}_{10}$ ) [ $\text{cm}^2$ ],
- Indication whether sealed or as-operated test was done,
- Leakage distribution (percentage of envelope leakage area at floor, wall, and ceiling height),
- Height of the building,
- Local terrain,
- Shelter coefficients.

The  $\text{ACH}_{50}$  and  $\text{ELA}_{10}$  inputs are converted to  $C_r$  and  $n$  using the following expressions (Beausoleil-Morrison, 2000):

$$n = \frac{\ln\left(\frac{12699.148 \cdot \text{ACH}_{50} \cdot V}{3600 \cdot \text{ELA}_{10} \cdot 10^{0.5}}\right)}{\ln\left(\frac{50}{10}\right)} \quad (7)$$

$$C_r = \frac{\text{ELA}_{10}}{12699.148 \cdot 10^{n-0.5}} \quad (8)$$

$ELA_{10}$  is determined from a multi-point test using Equation 3 in CAN/CGSB 149.10-2019:

$$ELA_{10} = 11.57 \cdot \sqrt{\rho_r} \cdot C_r \cdot 10^{n-0.5} \tag{9}$$

Once  $C_r$  and  $n$  are determined from the inputs, the sealed or as-operated indicator is checked. If the test was sealed, AIM-2 computes additional leakage from gas-fired space heating and service hot water system flues which would be sealed during a sealed airtightness test, but would be open during building operation. The building height, local terrain, and shelter coefficients are used to calculate the local wind conditions at the building from the wind conditions measured at the meteorological site. Finally, building height and leakage distribution are used to determine stack-effect infiltration during building operation. Further details on the AIM-2 model are omitted here for clarity, and the interested reader is directed to Walker & Wilson (1990) or Bradley & Riley (1993) for further details.

In every building simulation tool, regardless of how the inputs are specified, the infiltration flow rate is ultimately expressed as either a mass [kg/s] or volumetric [L/s] flow rate into and out of the conditioned space, with the incoming air flow having a drybulb temperature and humidity ratio equal to current outdoor air. This is then used to compute an energy balance of the space.

## 2.5 Summary of Proposed Changes in PCF 1819

PCF 1819 proposes changes to the performance compliance paths in Subsections 9.36.5 and 9.36.7, as well as the airtightness levels in Subsection 9.36.6. For Subsection 9.36.6, PCF 1819 proposes to remove  $ACH_{50}$  from Tables 9.36.6.4.-A and B, leaving  $NLR_{50}$  or  $NLA_{10}$  (both area-normalized metrics) as optional metrics to determine airtightness level for prescriptive path compliance. In the performance path, both reference and proposed airtightness inputs are changed. The following subsections describe the current requirements and proposed changes for airtightness modelling in the performance paths.

### 2.5.1 Changes to Reference Model in Performance Path

For the reference model, Clauses 9.36.5.14.(2)(d) and (e) are changed in PCF 1819, and a new Sentence is proposed after 9.36.5.14.(2). Figure 2 compares the 2020 NBC (a) and PCF 1819 (b) requirements for determining reference building airtightness performance, where the units of  $NLR_{50}$  are  $L/(s \cdot m^2)$  @  $\Delta P=50$  Pa. The requirements to set the flow exponent,  $n$ , are effectively unchanged.

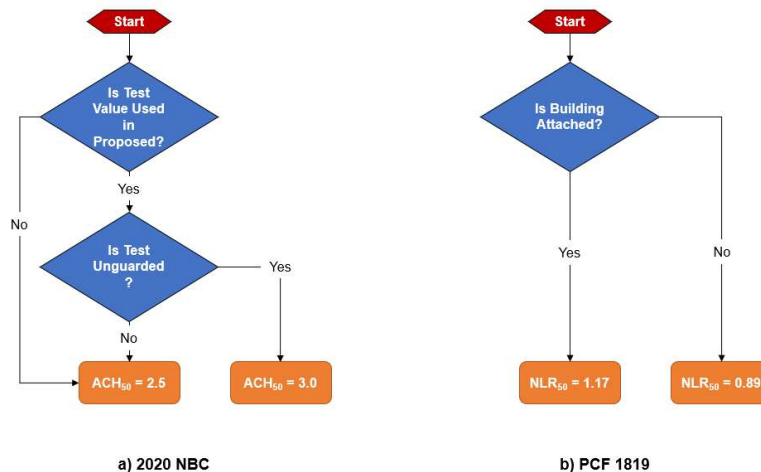


Figure 2. Comparing 2020 NBC and PCF 1819 reference building airtightness performance inputs

It can be seen in Figure 2 that  $NLR_{50}$  replaces  $ACH_{50}$  under PCF 1819, and the criterion to select the high or lower reference airtightness performance also changes. Under the 2020 NBC, 3.0  $ACH_{50}$  is only used if an unguarded test value is used in the proposed building. For all other cases, 2.5  $ACH_{50}$  are used. The 3.0  $ACH_{50}$  exception is intended to balance the over-estimation of infiltration rate in the proposed model arising from using a measured unguarded  $ACH_{50}$  directly as airtightness performance. Practically, a portion of the unguarded  $ACH_{50}$  flow rate measured during the test is from adjacent units nominally at a temperature similar to the conditioned space, and therefore, does not induce an additional heating or cooling load. There are also generally no wind-driving forces across partition surfaces. If an unguarded  $ACH_{50}$  test result is passed directly as an input to HOT2000, or any other infiltration model, the partition surfaces, for the purposes of infiltration modelling, are assumed to be exposed directly to outdoor conditions which is not a realistic assumption.

Under PCF 1819, attached dwellings, in all cases, use the higher  $NLR_{50}$  of 1.17 L/(s·m<sup>2</sup>) @ ΔP=50 Pa, and detached homes use 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa for their reference models. Sentence 9.36.5.14.(3), as proposed in PCF 1819, implicitly states that the reference  $NLR_{50}$  values are the nominal performance of the exterior/exposed building surfaces ( $A_e$ ), and to convert them to a total infiltration flow rate (i.e., L/s) the normalized leakage rate is multiplied by the exterior area  $A_e$ . This is the appropriate area to use since it is the area over which outdoor air infiltration is occurring.

### 2.5.2 Changes to Proposed Model in Performance Path

For the proposed model, Sentences 9.36.5.10.(9) and (10) are changed in PCF 1819 to use  $NLR_{50}$  as the governing airtightness performance metric. Figure 3 compares the current 2020 NBC method (a) and the proposed method in PCF 1819 (b) to specify airtightness performance for the proposed model in the performance compliance path.

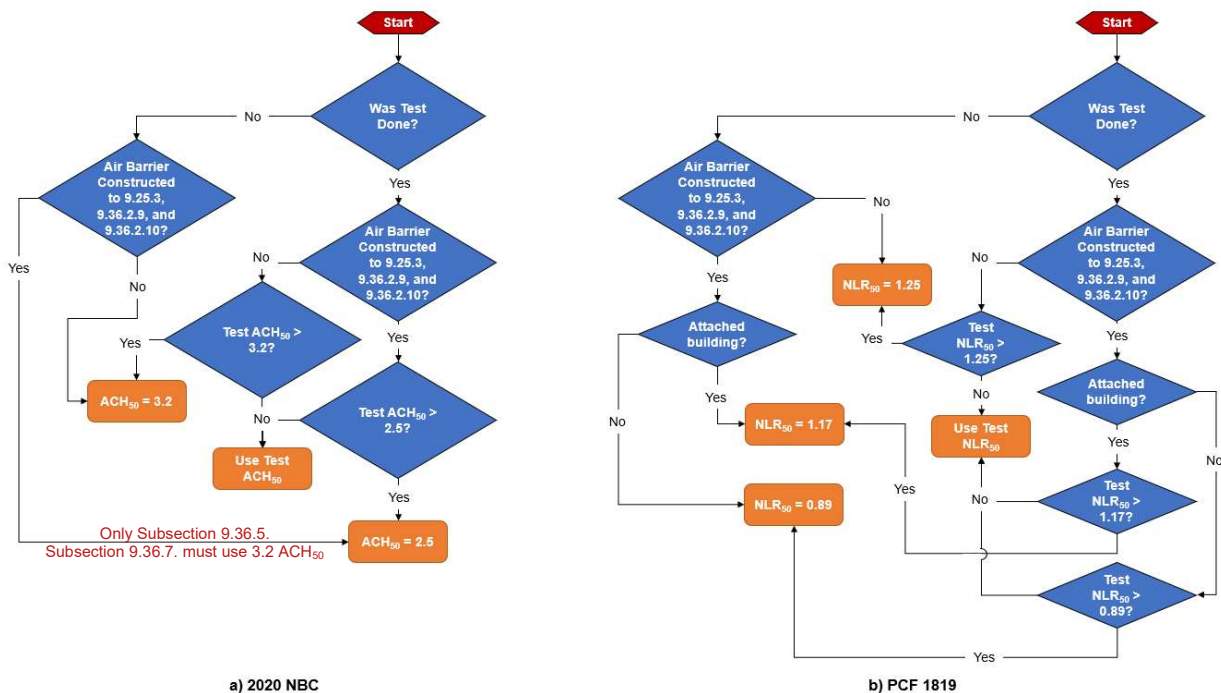


Figure 3. Comparing 2020 NBC and PCF 1819 proposed building airtightness performance inputs

PCF 1819 replaces 3.2  $ACH_{50}$  with 1.25 L/(s·m<sup>2</sup>) at ΔP=50 Pa, and 2.5  $ACH_{50}$  is replaced with either 0.89 or 1.17 L/(s·m<sup>2</sup>) at ΔP=50 Pa; the 2020 NBC does not differentiate by attachment type when setting the prescriptive airtightness performance in the proposed building when the air barrier is constructed in accordance with

Subsection 9.25.3. and Articles 9.36.2.9. Both the current provisions in the 2020 NBC, and those proposed in PCF 1819, allow the code user to use a test value determined using standard CAN/CGSB 149.10-2019 to gain credit for achieving an airtight design. Described in Section 2.4 of this report,  $ACH_{50}$  is a direct input to HOT2000. Under the 2020 NBC the measured value is passed directly to the model, regardless of the test setup (guarded or unguarded). Stated previously in Section 2.5.1 of this report, unguarded  $ACH_{50}$  values are an over-estimation of exterior air infiltration, and to balance against this over-estimation, a higher  $ACH_{50}$  is subsequently used in the reference building. PCF 1819 provides the following expression to convert the measured  $NLR_{50}$  ( $NLR_{50,measured}$ ) to  $ACH_{50}$  for use in the energy model ( $ACH_{50,model}$ ):

$$ACH_{50,model} = 3.6 \cdot \left(\frac{A_e}{V}\right) \cdot NLR_{50,measured} \quad (10)$$

Equation (10) is a formulation of Equation (6), except  $A_e$  is used in all cases (guarded and unguarded test data). This implicitly assumes that the nominal leakage (i.e.,  $NLR_{50}$ ) performance of the partitions and exterior air barriers are approximately equal. Guarded and unguarded data collected by Rosen (2021) for 34 attached new construction Part 9 units in Ontario suggested that, on average, this assumption was acceptable with an average error of -4.7% (estimate from using unguarded value has a leakage rate 4.7% lower than the measured guarded value) with a standard deviation of 14.0%.

### 2.5.2.1 Tiered Energy Performance Compliance: Performance Path

There is a notable deviation in how the proposed building airtightness performance is modelled in the Tiered Energy Performance Compliance Performance Path of Subsection 9.36.7. compared to Subsection 9.36.5. in the 2020 NBC. As was shown in Figure 3, if no airtightness test is conducted 2.5  $ACH_{50}$  may be used in the proposed model if the following two conditions are true: 1) the air barrier is constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., and 2) compliance is being sought under the performance path in Subsection 9.36.5. If performance compliance is being sought under the Tiered performance path in Subsection 9.36.7., Sentence 9.36.7.3.(9) effectively states that if no airtightness test is performed then only 3.2  $ACH_{50}$  can be used in the proposed model. This discrepancy between Subsections 9.36.5. and 9.36.7. was discussed at the 2020-01 Meeting of the Standing Committee on Energy Efficiency. Per the minutes:

- *SC-EE noted that at the time Section 9.36. was developed, the SC-HSB did not have data to substantiate the assumed value of 2.5 ACH @ 50 Pa attributed to the comprehensive air sealing measures of 9.36.2.9. and 9.36.2.10. There remains insufficient data to support the assertion of 2.5 ACH @ 50 Pa as a reliable representation for the prescriptive measures in Article 9.36.2.9, 9.36.2.10 as supported by notes provided by NRCan.*
- *SC-EE agreed to model the proposed house using an ACH value equal to the upper default given in 9.36.5.10.(9) where no airtightness test is conducted and to revisit all airtightness requirements in Section 9.36., including the remaining requirements in 9.36.5., in the 2020-2025 code cycle*

PCF 1819 proposes the same approach in Subsection 9.36.5. be used in 9.36.7.; 0.89 L/(s·m<sup>2</sup>) @  $\Delta P=50$  Pa is used as the airtightness performance in the proposed building if no airtightness test is conducted and the air barrier is constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10. and the building is detached, 1.17 L/(s·m<sup>2</sup>) @  $\Delta P=50$  Pa is used in the proposed building if no airtightness test is conducted and the air barrier is constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10. and the building is detached, otherwise 1.25 L/(s·m<sup>2</sup>) @  $\Delta P=50$  Pa is used.

It is also important to note that Sentence 9.36.5.10.(9)(b) in the 2020 NBC states that if an airtightness test is performed, then the proposed model uses an airtightness performance as defined in Sentence 9.36.5.10.(9) can be selected. Reviewing Sentence 9.36.5.10.(9), the code user is provided 3 options: use 3.2  $ACH_{50}$ , use 2.5  $ACH_{50}$  if air barrier is constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., or use the measured

performance. Thus, regardless of the outcome of the airtightness test, the code user can always optionally use 2.5 ACH<sub>50</sub> in the proposed model, and therefore never be penalized for achieving an airtightness performance below reference. To illustrate, consider an example of a code user seeking Tiered energy performance path compliance. They conduct an airtightness test, achieve 3.8 ACH<sub>50</sub>, and refer to Clause 9.36.7.3.(9)(b) to determine what airtightness performance to use in the proposed model. Clause 9.36.7.3.(9)(b) indicates that “the appropriate airtightness value set out in Sentence 9.36.5.10.(9) can be selected.” Sentence 9.36.5.10.(9) provides three options: 3.2 ACH<sub>50</sub>, 2.5 ACH<sub>50</sub> if the air barrier was constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., or the measured airtightness. Since 3.8 ACH<sub>50</sub> is greater than the 2.5 ACH<sub>50</sub> in the reference, the code user could optionally use 2.5 ACH<sub>50</sub> in the proposed model (presuming they constructed their air barrier to the extra requirements) and therefore, not incur any energy performance penalty (or credit) for not meeting the airtightness performance.

## 3 Methodology

This report assessed impacts of PCF 1819 on energy compliance outcomes in both the prescriptive and performance paths of Section 9.36 of the NBC. The 240 new construction building archetypes from Asaee & Ferguson (2019) were used to explore how PCF 1819 impacts different building types and attachments.

PCF 1819 affects compliance calculations and determinations of several compliance pathways in Section 9.36; therefore, to fully assess how the PCF will impact Section 9.36., each of the affected pathways needs to be considered. From reviewing the changes proposed in the PCF the following “performance” path scenarios were defined, and the impacts of compliance outcomes to those scenarios from changes in PCF 1819 were assessed:

- Detached building:
  - No airtightness test performed:
    - Air barrier constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10.:
      - Compliance with Subsection 9.36.5.;
      - Compliance with Subsection 9.36.7.
    - Air barrier *not* constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10.;
  - Airtightness test performed.
- Attached building:
  - No airtightness test performed:
    - Air barrier constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10.:
      - Compliance with Subsection 9.36.5.;
      - Compliance with Subsection 9.36.7.
    - Air barrier *not* constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10.;
  - Guarded airtightness test performed;
  - Unguarded airtightness test performed.

To assess and compare compliance outcomes between 2020 NBC and PCF 1819 for each of these scenarios the archetypes were modelled in the simulation tools described later in Section 3.1 of this report. To enable a more focused and detailed analysis, four archetypes were selected from the 240 archetypes: two attached and two detached. For each attachment type, one archetype was selected which has a relatively high  $A_e/V$  ratio, and one with a relatively low  $A_e/V$  ratio. This was done to capture the extreme ranges of changes to modelled airtightness in the performance path.

Impacts to the prescriptive compliance path were assessed by evaluating how airtightness level achieved will vary for all 240 archetypes. The final assessment in this report is a case study of how compliance outcomes will change for the 240 archetypes if they are seeking compliance with Tier 3 in Climate Zone 7A (Edmonton, AB) and are using airtightness testing as part of their compliance.

### 3.1 Compliance Calculation Tools

The building performance simulation tool HOT2000 (NRCan, 2018) was used to evaluate the building loads and energy consumption of reference and proposed building archetypes under 2020 NBC and PCF 1819 performance path calculation requirements. HOT2000 was previously tested against the Home Energy Rating System Building Energy Simulation Test (HERS BESTEST) (Haltrecht & Fraser, 1997). More recently HOT2000 v11.3 was evaluated against ASHRAE Standard 140-2014 (Parekh, Charron, Poirer, & Roux, 2018). That study found the heating energy results calculated by HOT2000 were within the range of benchmark values listed in the ASHRAE Standard, and the whole building energy consumptions were, overall, within acceptable ranges. They did, however, find that HOT2000 generally under-predicted cooling energy consumption. Currently space cooling systems are not mandatory for Part 9 buildings, and most Canadian climates are heating-dominated with only an

estimated 2.5% of total secondary energy consumption in the residential sector being attributed to space cooling in 2016 (NRCan, 2023). For this study HOT2000 version 11.8 was used.

HOT2000 model inputs and post-processing were managed using the Housing Technology Assessment Platform (HTAP) developed by NRCan (2015). Key features of HTAP making it beneficial for the current analysis include its ability to convert models to code reference models as defined in Subsection 9.36.5. of the 2020 NBC, parallel processing of models, gathering and post-processing of model outputs into central databases, and ability to apply upgrade measures consistently across a range of models. HTAP is an open-source tool which provides transparency to the analysis and assumptions used. The source code of HTAP can be found at NRCan (2015). The specific branch of the source code used was “NBC\_Ruleset\_Updates” with commit hash 4225b92. Further details on HTAP may be found on the source code webpage.

## 3.2 Archetypes

The 240 new construction archetypes from Asaee & Ferguson (2019) were used to analyze the impact PCF 1819 has on minimum code compliance outcomes. These new archetypes represent a significant increase in number of building topologies considered in code impact analyses compared to previous work which used eleven archetypes (2011a; 2011b). The new archetypes are publicly available online (NRCan, 2020) and reflect construction in eight major housing markets in Canada:

- Atlantic (NL, NS, NB, PE);
- Québec (QC);
- Greater Toronto Area (GTA);
- North and East Ontario (ON);
- Prairies (MB, SK, AB);
- British Columbia – Lower Mainland (BC-LM);
- British Columbia – Interior (BC-INT);
- Territories (North).

For each market, 15 single-detached and 15 double/row buildings were selected from the EnerGuide for Housing Database (EGHD) (Blais, Parehk, & Roux, 2005) with vintages no earlier than 2015. Archetypes were selected for each housing market such that a range of the following dwelling characteristics were expressed in the new archetype set:

- Number of stories (1-3);
- Attachment type;
- Conditioned floor areas (50-450 m<sup>2</sup>);
- Glazing ratio (0.05-0.35);
- Foundation type;
- Ceiling/roof type.

By expressing a broad range of key building characteristics, the range of impacts of proposed code changes can be explored.

A key characteristic of the archetypes to consider for this impact analysis is the surface area-to-volume ratio,  $A/V$ , which is used to relate  $NLR_{50}$  to  $ACH_{50}$  for a given building, shown previously in Equation (6). Figure 4 plots the distributions of the “exposed” area-to-volume ratio,  $A_e/V$ , for the 120 detached and 120 attached archetypes, and Table 1 a statistical summary of  $A_e/V$  for the archetypes.

Table 1. Summary statistics of archetype exterior area-to-volume ratios

Exterior Surface Area-to-Volume Ratio, $A_e$ [ $m^2/m^3$ ]					
Attachment Type	Number of Archetypes	Average	Standard Deviation	Maximum	Minimum
Detached	120	0.808	0.169	1.70	0.547
Attached	120	0.707	0.169	1.29	0.405

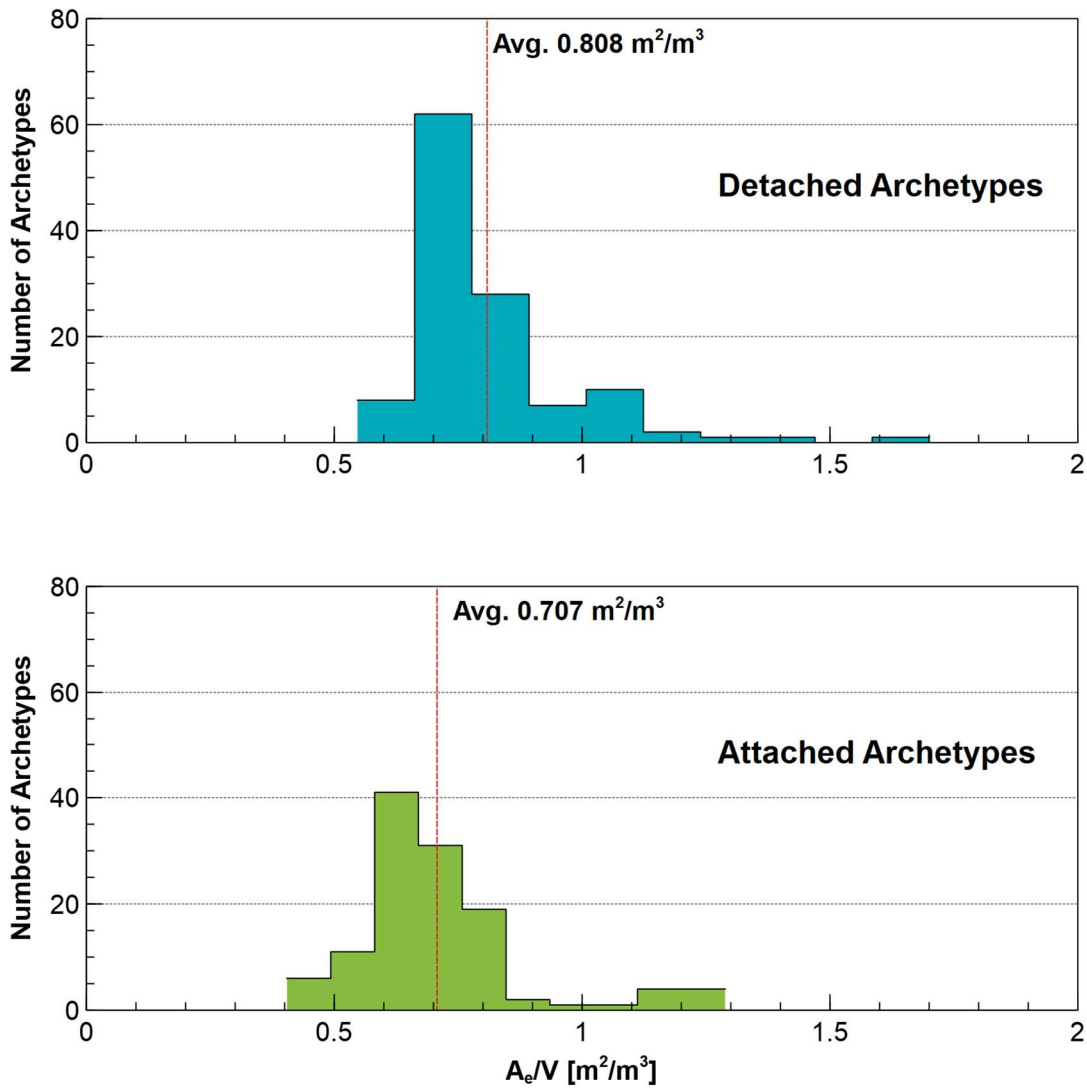


Figure 4. Distribution of exterior area to volume ratio of the new construction archetypes

The average  $A_e/V$  values in Figure 4 differ from those reported in Wills, Macdonald, & Knudsen (2020) due to updates on the method HTAP uses to calculate exposed areas of walkout foundations, but are not significantly different from what was previously calculated.

Stated previously, NRCan OEE developed estimates for the total area,  $A_T$ , of the 120 attached archetypes. The total area to volume,  $A_T/V$ , of the attached archetypes are provided in Figure 5.

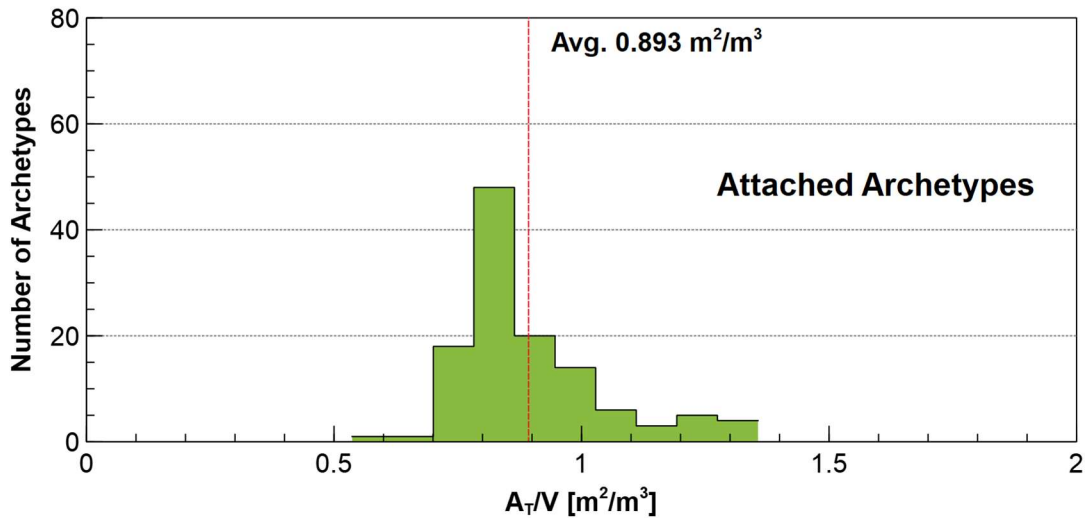


Figure 5. Distribution of total area to volume ratio of the new construction attached archetypes

Further details on the archetypes are omitted for clarity, and the interested reader is directed to Asaee & Ferguson (2019) for additional details.

Rather than utilize all 240 archetypes, a subset of four archetypes were selected for detailed analysis and are described in Table 2.

Table 2. Summary of archetypes used for detailed analysis

Archetype	Type	Storeys	Floor Area [ft <sup>2</sup> ]	Conditioned Volume [m <sup>3</sup> ]	$A_e/V$ [m <sup>2</sup> /m <sup>3</sup> ]	$A_T/V$ [m <sup>2</sup> /m <sup>3</sup> ]	Foundation
ERS-4875	Row-end	2	1680	443	0.543	0.845	Basement
ERS-3060	Semi-detached	2	1670	411	0.783	0.864	Basement
ERS-1073	Single-detached	2	2660	629	0.607	0.607	Basement
ERS-1048	Single-detached	1	2280	406	1.07	1.07	Basement

These archetypes were selected to represent both attached and detached dwellings, and both relatively large and small  $A_e/V$  ratios relative to the distributions in Figure 4.

### 3.3 Climate

For this study, climate locations for Toronto, ON (Climate Zone 5) and Edmonton, AB (Climate Zone 7A) were considered. The “Wth110” weather database packaged with HOT2000 was used to provide annual climate conditions for those locations which have annual heating degree days (base 18 °C) of 3520 and 5120, respectively. Climate Zone 5 was selected to represent warmer climates such as the Greater Toronto Area, Kamloops, and Kelowna, and Climate Zone 7A was selected to represent population centres in colder climates such as Edmonton, Winnipeg, Québec City, and Calgary.

### 3.4 Tier 3 Case Study

It is assumed that the greatest impact of PCF 1819 on the performance path will be observed when airtightness testing is used as a measure for compliance in the Tiered path. To analyze the potential impact, the 240 new construction archetypes were used to develop two Tier 3 solution sets: one which complies with Tier 3 under the performance path calculation requirements in 2020 NBC, and one complying with Tier 3 under the requirements of PCF 1819. For both solution sets a combination of airtightness testing, envelope, and equipment energy conservation measures were considered to meet Tier 3. For attached homes, it was assumed that unguarded testing is used for compliance.

For both solution sets, Climate Zone 7A (Edmonton, AB) was used, and Tier 3 was achieved for the archetypes using the measures described in Table 3. Note that there are two sets of measures: one for archetypes with conditioned volumes < 300 m<sup>3</sup>, and one for archetypes with conditioned volumes ≥ 300 m<sup>3</sup>. This is due to separate Tier 3 compliance requirements based on conditioned volume. Per Table 9.36.7.2. in the 2020 NBC, buildings with a conditioned volume greater than 300 m<sup>3</sup> achieve Tier 3 if the percent improvement is greater than or equal to 20% and the percent heat loss reduction is greater than or equal to 10%. For homes with a conditioned volume less than 300 m<sup>3</sup>, Tier 3 is achieved with percent improvement and heat loss reductions greater than or equal to 10% and 5%, respectively.

Table 3. Climate Zone 7A Tier 3 packages for impact analysis

Building Component	Building Conditioned Volume	
	< 300 m <sup>3</sup>	≥ 300 m <sup>3</sup>
Above-grade Walls [RSI]	3.70 (R 21)	
Ventilation System	No heat recovery	HRV 78% SRE @ 0 °C
Space Heating System	98% AFUE Furnace	
Service Hot Water	0.88 EF Gas-fired hot water tank	
Airtightness	<b>Variable [0.6 to 4.0 ACH<sub>50</sub>]</b>	

The airtightness performance in Table 3 is listed as “variable”; for both solution sets the airtightness performance required to achieve Tier 3 was determined individually for each archetype using the following approach:

- A golden section search (Kiefer, 1953) was used to find the “modelled” airtightness performance ( $ACH_{50,model}$ ) that minimized the difference between percent improvement of the proposed model and the Tier 3 target, keeping all other measures in Table 3 fixed.
- Once a solution was found, the percent heat loss reduction was checked against the Tier 3 target. If it was below the target, the golden section search was repeated to find the airtightness performance that minimized the difference between percent heat loss reduction and the Tier 3 target. Since airtightness measures affect both percent improvement and heat loss reduction, the second solution will yield a higher airtightness performance (to precisely meet the percent heat loss reduction) and achieve a percent improvement slightly above the Tier 3 target.

Once both solution sets were determined, the following three analyses were conducted.

The first analysis considered only the 2020 NBC-compliant solution set. The calculated performance of each archetype in that solution set was re-evaluated under the provisions of PCF 1819; the solutions themselves were not altered, only the approach to calculating their performance compliance. The objective of this analysis was to evaluate how designs that are currently compliant with 2020 NBC will be affected by PCF 1819. The expected outcomes were either 1) no change and they still comply, 2) their calculated performance improves under PCF 1819, or 3) they no longer comply and will have to implement additional measures to regain compliance.

The second analysis compared the “measured”  $ACH_{50}$  ( $ACH_{50,measured}$ ) performance required by each archetype to meet Tier 3 compliance under the provisions of 2020 NBC and PCF 1819. For the 2020 NBC solution set all  $ACH_{50,model}$  values determined for each archetype are equal to  $ACH_{50,measured}$  since 2020 NBC uses  $ACH_{50,measured}$  directly for  $ACH_{50,model}$ . Under PCF 1819 Equation (10) is used to determine  $ACH_{50,model}$ . When  $NLR_{50,measured}$  is derived from  $A_T$ , which would be the case for an unguarded test, then recasting Equation (10) in terms of  $ACH_{50,measured}$  yields:

$$ACH_{50,model} = 3.6 \cdot \left(\frac{A_e}{V}\right) \cdot \left(\frac{ACH_{50,measured} \cdot V}{3.6 \cdot A_T}\right) = \frac{A_e}{A_T} \cdot ACH_{50,measured} \quad (11)$$

For guarded or detached building airtightness testing  $A_T = A_e$  and  $ACH_{50,model} = ACH_{50,measured}$ . Equation (11) was used to determine  $ACH_{50,measured}$  for all archetypes in the PCF 1819 solution set.

The final analysis compared annual operational energy use estimates between the 2020 NBC and PCF 1819 solutions. The estimates were produced using the following assumptions:

- The proposed model of the attached buildings in the 2020 NBC solution set were re-simulated in HOT2000 using “guarded” airtightness performance to estimate annual operational energy performance. Recall that for this solution set  $ACH_{50,measured}$  is used directly as  $ACH_{50,model}$  which is an over-estimation of operational infiltration of outdoor air. Guarded performance is estimated using Equation (11).
- The proposed models of the detached archetypes in the 2020 solution set, and all the proposed models in the PCF 1819 solution set, were used to estimate annual operational energy performance

The annual climate described in Section 3.3 of this report was used to generate annual energy estimates, and does not necessarily reflect future climates.

## 4 Results

Section 4.1 of this report provides the results of the impact analyses for the performance path using the archetypes with the relatively large and small  $A_e/V$  ratios described previously in Table 2. Section 4.2 of this report provides the results of the impact analysis for the prescriptive path. Finally, Section 4.3 of this report provides the results of the Tier 3 case study.

### 4.1 Changes to Compliance in the Performance Path

The performance paths in Subsection 9.36.5. and 9.36.7. of the 2020 NBC both use a reference versus proposed approach to determine if a building design is compliant. PCF 1819 changes the magnitude of annual heat loss due to infiltration in the reference model, and the scale of the change is not equal across all building topologies. PCF 1819 also changes how unguarded test data are pre-processed for modelling the proposed building, and the magnitude of the change relative to 2020 NBC also varies with building topology. Using the four archetypes described previously in Table 2, the impacts to performance path compliance outcomes were assessed for the different compliance scenarios described previously in Section 3 of this report.

#### 4.1.1 Detached Buildings

For detached buildings, the 2020 NBC requires the reference building be modelled with an airtightness performance of 2.5 ACH<sub>50</sub>, and PCF 1819 would instead require an NLR<sub>50</sub> of 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa. Using Equation (6) in this report, the exterior area-to-volume ratio,  $A_e/V$ , where 2.5 ACH<sub>50</sub> equates to 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa is 0.780 m<sup>2</sup>/m<sup>3</sup>. This is referred to in this report as the “critical” ratio ( $A_e/V_{critical}$ ). Any detached building with a  $A_e/V$  greater than 0.780 m<sup>2</sup>/m<sup>3</sup> will have an increased infiltration rate in its reference model, and therefore, higher energy consumption (i.e., lower performance). Inversely, any detached building with a  $A_e/V$  less than 0.780 m<sup>2</sup>/m<sup>3</sup> will have a decreased infiltration rate in its reference model, and therefore, lower energy consumption (i.e., higher performance).

Plotted in Figure 6 are the equivalent reference NLR<sub>50</sub> values that would be used under 2020 NBC requirements for the 120 detached archetypes, back-calculated from a reference ACH<sub>50</sub> of 2.5 and using the  $A_e/V$  ratios presented previously in Figure 4. The equivalent NLR<sub>50</sub> values are plotted versus conditioned volume of the archetypes.

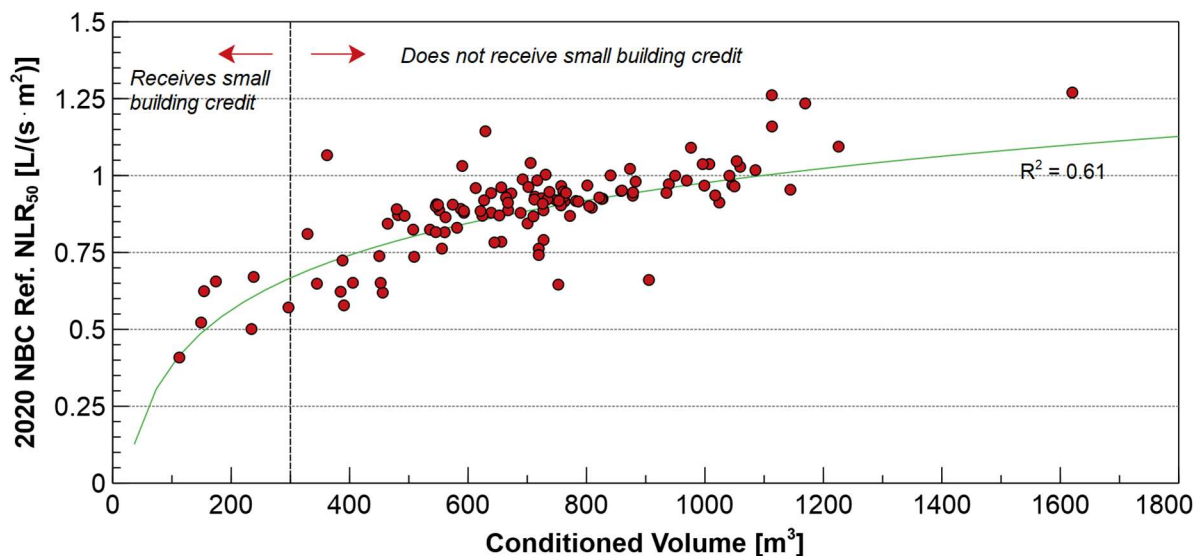


Figure 6. 2020 NBC equivalent NLR<sub>50</sub> for reference model of detached archetypes

There are a few key observations that can be made from Figure 6. First, the general trend of the data is that the equivalent reference  $NLR_{50}$  decreases (airtightness performance increases) as the conditioned volume decreases for the detached archetypes. This trend agrees with the  $A_e/V$  versus conditioned volume data presented in PCF 1819. In that data set, 8117 single-detached home data set from Ontario were shown to have an increasing  $A_e/V$  as conditioned volume reduced. Using Equation (6), it can be shown that when  $ACH_{50}$  is a fixed value the corresponding  $NLR_{50}$  is inversely proportional to  $A_e/V$ .

The other observation from Figure 6 is that under the 2020 NBC Tiered energy performance path buildings with conditioned volume  $< 300 \text{ m}^3$  receive a relaxation in performance compliance. The archetypes with volumes  $< 300 \text{ m}^3$  in Figure 6 would need to achieve an equivalent  $NLR_{50}$  values of 0.41 to 0.67  $\text{L}/(\text{s}\cdot\text{m}^2)$  @  $\Delta P=50 \text{ Pa}$  to begin collecting performance savings for airtightness, but they also need 10% less percent improvement to achieve the targeted tier compared to larger buildings and are currently not obligated to test for airtightness.

Table 4 provides the reference model  $ACH_{50}$  values under current 2020 NBC and proposed PCF 1819 requirements for the detached archetypes selected for detailed analysis (introduced previously in Table 2).

Table 4. Changes to the reference model  $ACH_{50}$ : Detached buildings

Archetype	Storeys	Floor Area [ft <sup>2</sup> ]	Conditioned Volume [m <sup>3</sup> ]	$A_e/V$ [m <sup>2</sup> /m <sup>3</sup> ]	Reference Model $ACH_{50}$	
					2020 NBC	PCF 1819
ERS-1073	2	2660	382	0.607	2.5	1.94
ERS-1048	1	2280	406	1.07		3.43

To understand the impact of this change to compliance outcomes, the reference model needs to be considered in tandem with the proposed model since it is the relative performance between reference and proposed that determines if a proposed design is compliant. Figure 3 showed that there are three or four possible airtightness performance inputs that may be used in the proposed building model depending on:

1. Whether the building is attached or detached,
2. Whether a test was performed, and
3. Whether the air barrier was constructed in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10.

A key parameter that is not shown in Figure 3 is that whether compliance with Subsection 9.36.5. or 9.36.7. is being sought which will also affect the proposed model airtightness performance. The following subsections provide the impact analyses for detached buildings seeking compliance under the performance path. The results are organized by whether an airtightness test is performed or not, and whether compliance is being sought through Subsection 9.36.5. or 9.36.7.

#### 4.1.1.1 No Airtightness Test Performed

If no airtightness test is done for performance compliance of a detached home, then the airtightness performance assumed in the proposed building will be dictated by two factors: whether compliance is being sought under Subsection 9.36.5. or 9.36.7., and construction of the air barrier. Starting with Subsection 9.36.5., if the air barrier is constructed in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., then the proposed building is permitted to use 2.5  $ACH_{50}$  as the airtightness performance, otherwise 3.2  $ACH_{50}$  is to be assumed, shown in Figure 3(a). In Subsection 9.36.7., if no airtightness test is performed, then *only* 3.2  $ACH_{50}$  may be used. PCF 1819 replaces 2.5  $ACH_{50}$  with 0.89  $\text{L}/(\text{s}\cdot\text{m}^2)$  @  $\Delta P=50 \text{ Pa}$  and 3.2  $ACH_{50}$  with 1.25  $\text{L}/(\text{s}\cdot\text{m}^2)$  @  $\Delta P=50 \text{ Pa}$ , and also allows for a higher airtightness performance in the proposed building under Subsection 9.36.7. if the air barrier is constructed in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10. (0.89  $\text{L}/(\text{s}\cdot\text{m}^2)$  @  $\Delta P=50 \text{ Pa}$  versus 1.25  $\text{L}/(\text{s}\cdot\text{m}^2)$  @  $\Delta P=50 \text{ Pa}$ ). Therefore, impacts on the performance path

compliance outcomes change under PCF 1819 for Subsection 9.36.5. and 9.36.7. need to be considered separately.

**4.1.1.1.1 Subsection 9.36.5 with Air Barrier Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.**

If the proposed building’s air barrier is constructed in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10. (extra prescriptive measures), then under both 2020 NBC and PCF 1819 modelling requirements the reference and proposed buildings are modelled with the same airtightness performance for compliance under Subsection 9.36.5. Table 5 provides the reference and proposed model airtightness performance inputs for detached archetypes ERS-1073 and ERS-1048.

Table 5. Reference and proposed airtightness performance for no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Archetype	Reference ACH <sub>50</sub>		Proposed ACH <sub>50</sub>	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
ERS-1073	2.5	1.94	2.5	1.94
ERS-1048		3.43		3.43

While both the 2020 NBC and PCF 1819 do not penalize for no airtightness testing when the air barrier is constructed with the extra prescriptive measures (both reference and proposed use the same airtightness performance), PCF 1819 does alter the *magnitude* of infiltration relative to 2020 NBC. This in turn alters the proportional contribution of space conditioning loads to the total annual regulated loads<sup>1</sup> of the building, which may affect the compliance of a building design that has implemented trade-offs in performance to comply.

To explore this impact, HTAP was used to generate code-reference models of archetypes ERS-1073 and ERS-1048 for Climate Zones 5 and 7A (Toronto and Edmonton, respectively) under both 2020 NBC and PCF 1819 modelling requirements. All archetypes were modelled with code-minimum gas-fired furnaces and service hot water. Energy conservation measures were then applied to the reference models, and the efficacy of those measures were evaluated and compared between performance path calculation requirements in 2020 NBC and PCF 1819. Two measures were considered: above-grade wall effective thermal resistance (RSI) measures was considered as a means to reduce the annual space heating load, and higher efficiency gas-fired service hot water systems were considered to reduce the annual hot water demands.

Figures 7 and 8 provide the percent improvement achieved from wall effective R-values of 18 to 30 (RSI 3.25 to 5.22) for the two archetypes using the 2020 NBC and PCF 1819 rules for modelling. The data is also summarized in Tables 6 and 7. Percent improvement is calculated as the percent reduction of the annual regulated loads of the proposed house relative to the reference, where the regulated loads include the annual energy consumption to meet space conditioning, ventilation, and service hot water loads. For compliance under Subsection 9.36.5. a proposed building must not have an annual regulated load greater than the reference; i.e., percent improvement must be greater than or equal to 0%.

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<sup>1</sup> Per Sentence 9.36.5.4.(1) in the 2020 NBC regulated loads include site/secondary energy consumption for space conditioning, ventilation, and service hot water. Appliance and lighting (plug loads) are excluded.

Table 6. Wall measures percent improvement for ERS-1073, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> ·K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	1.4%	1.5%	1.5%	1.6%
3.51	3.4%	3.6%	3.5%	3.7%
3.85	7.1%	7.2%	7.3%	7.8%
4.23	8.8%	9.0%	9.1%	9.6%
4.59	10.6%	10.9%	11.0%	11.6%
4.89	11.6%	12.1%	12.2%	12.8%
5.22	12.9%	13.3%	13.5%	14.2%

Table 7. Wall measures percent improvement for ERS-1048, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> ·K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	1.2%	1.1%	1.2%	1.1%
3.51	2.7%	2.4%	2.8%	2.6%
3.85	4.2%	4.0%	4.6%	4.4%
4.23	5.7%	5.5%	6.2%	5.9%
4.59	6.9%	6.6%	7.5%	7.1%
4.89	7.7%	7.4%	8.4%	8.0%
5.22	8.6%	8.2%	9.2%	8.9%

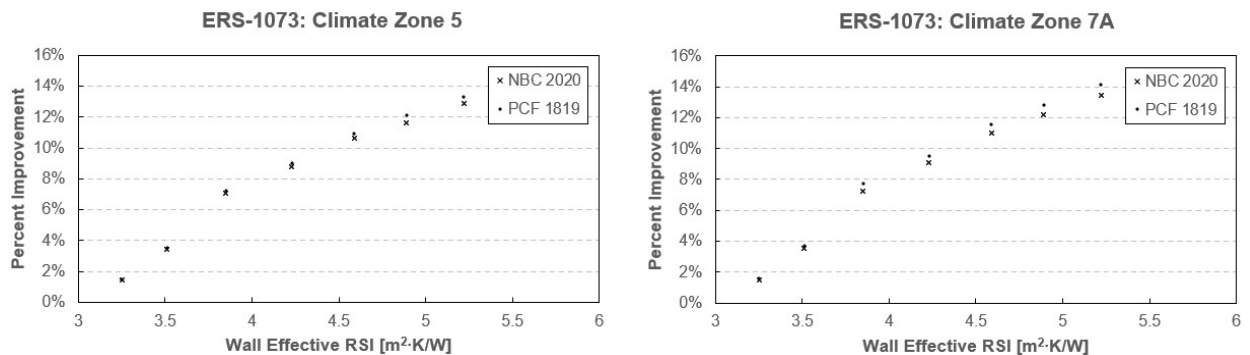


Figure 7. Subsection 9.36.5. wall measures percent improvement for ERS-1073, no airtightness test and air barrier constructed with extra prescriptive measures

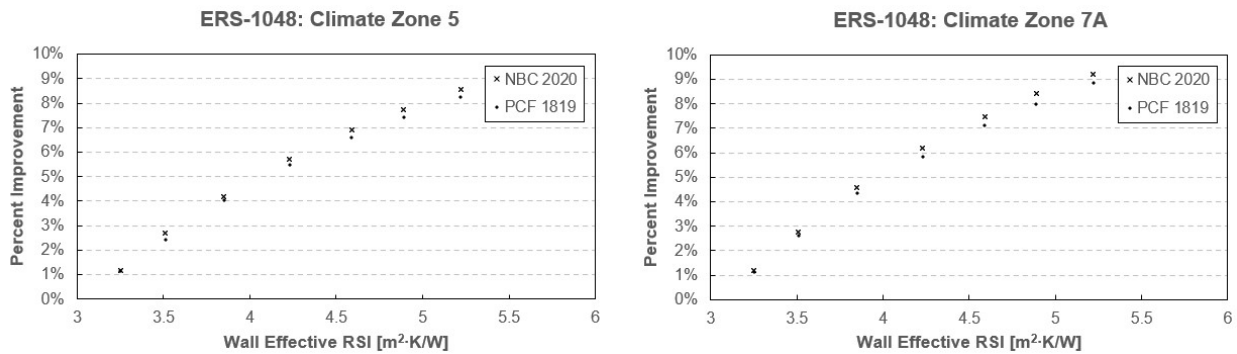


Figure 8. Subsection 9.36.5. wall measures percent improvement for ERS-1048, no airtightness test and air barrier constructed with extra prescriptive measures

Comparing Figures 7 and 8 it can be seen that under the proposed changes in PCF 1819 the percentage improvement calculated from above-grade wall measures increases for archetype ERS-1073 compared to 2020 NBC, whereas for archetype ERS-1048 the inverse occurs and the wall measures are given less credit under PCF 1819 compared 2020 NBC. To understand why the changes in performance credit occur, the breakdown of reference building annual envelope heat loss by component, and the annual regulated load energy consumption by end-use, for ERS-1073 were first plotted in Figure 9 for both Climate Zones 5 and 7A.

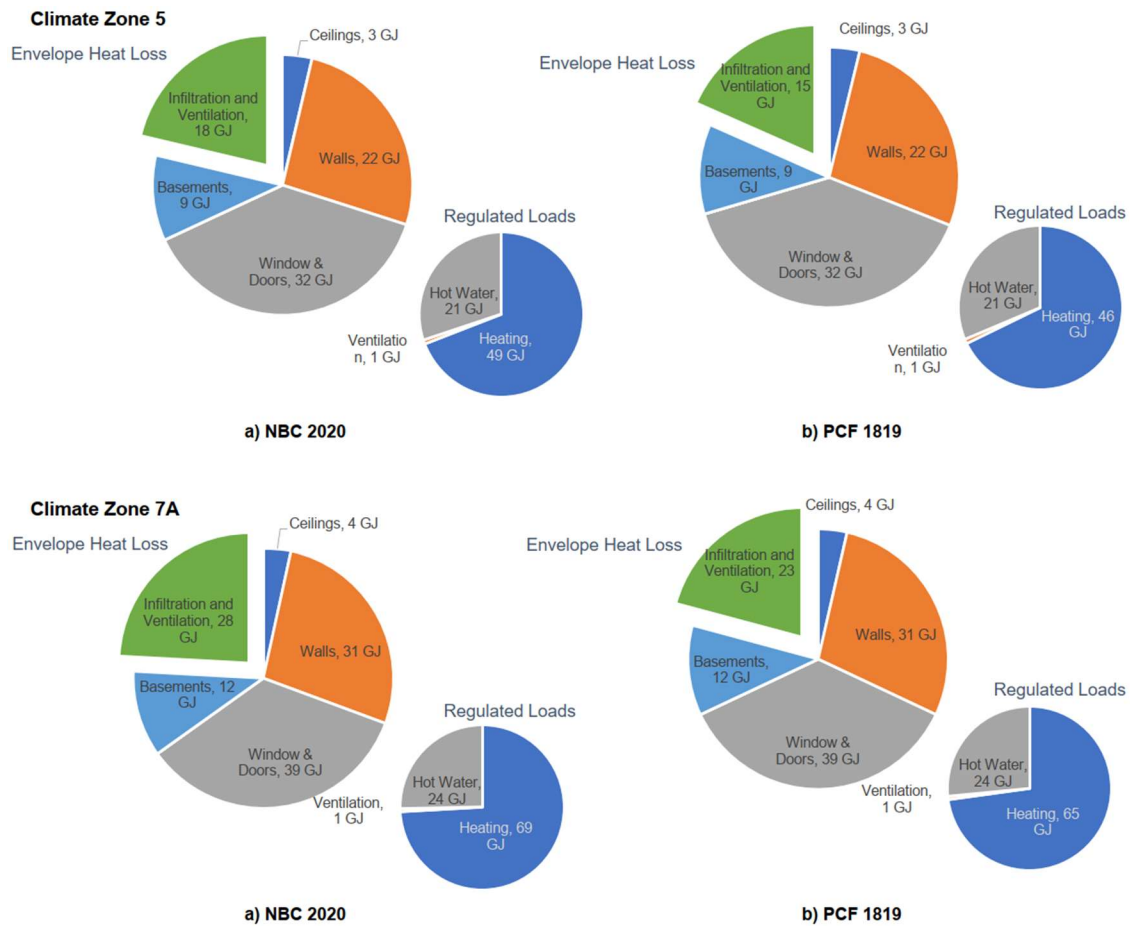


Figure 9. Reference building annual energy heat loss and regulated energy consumption: ERS-1073

Total annual heat losses through above-grade walls are the same under both 2020 NBC and PCF 1819 calculations (31 GJ/year), but under PCF 1819 the *proportion* of above-grade wall heat loss to the total envelope heat loss is increased because the contribution from infiltration decreases. Therefore, measures to reduce heat loss through above-grade walls for ERS-1073 will have a greater *relative* impact on reducing total envelope heat loss compared to 2020 NBC. However, the reduction in infiltration heat loss under PCF 1819 also reduces the contribution of space heating to the total annual regulated load. Thus, measures that reduce space heating loads will achieve less relative performance improvements under PCF 1819 compared to measures which reduce ventilation and hot water energy consumption. The net impact is nearly zero, with PCF 1819 increasing the relative reduction of space heating loads from above-grade wall measures, but reducing the contribution of space heating loads to total regulated loads. As shown in Table 6, the “magnitude” of the percent improvement “change” between 2020 NBC and PCF 1819 is between 0.1 and 0.7% across the climates and range of wall measures considered (e.g., under 2020 NBC the percent improvement is calculated as 8.0%, and under PCF 1819 the change is 7.9%, yielding a “change” of 0.1%).

Unlike ERS-1073, archetype ERS-1048 will have an increased infiltration rate under PCF 1819 compared to 2020 NBC due to its  $A_e/V$  ratio being above  $A_e/V_{critical}$  ( $0.780 \text{ m}^2/\text{m}^3$ ). Therefore, the proportional contribution of above-grade walls to total envelope heat loss and space heating load will decrease, but the contribution of space heating to total annual load will increase, shown in Figure 10. Again, the impact of PCF 1819 for this archetype and scenario is nearly zero, with Table 7 showing reductions in savings between 0.1 and 0.4% when going from 2020 NBC to PCF 1819.

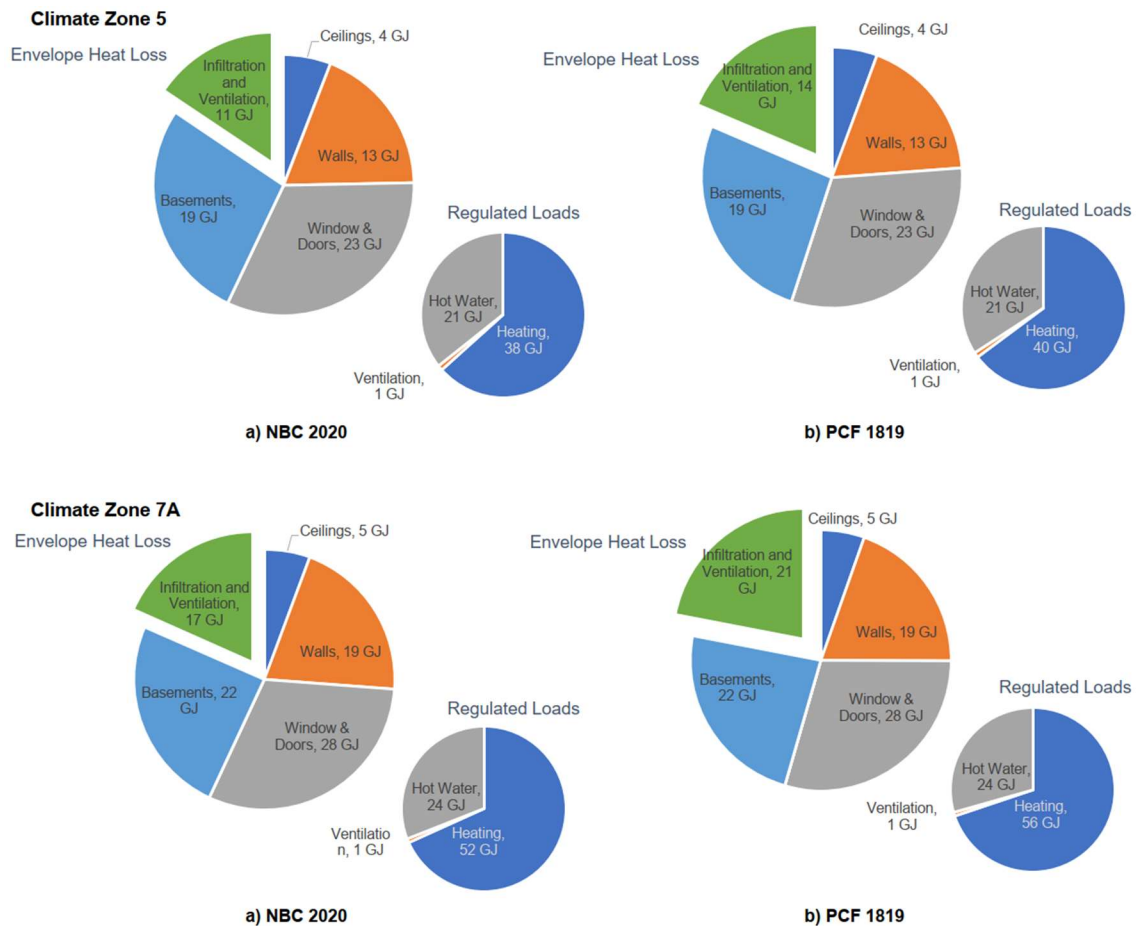


Figure 10. Reference building annual energy heat loss and regulated energy consumption: ERS-1048

The analysis was repeated with ERS-1073 and ERS-1048 using the service hot water measures described in Table 8.

Table 8. Service hot water measures considered

Service Hot Water System	Energy Factor (EF)
Code-reference gas hot water tank	0.601
Gas hot water with powervent tank	0.670
Gas-fired instantaneous	0.950

The percent improvement from the hot water measures are summarized in Tables 9 and 10 under the different climate and calculation scenarios.

Table 9. Hot water measures percent improvement for ERS-1073, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	2.3%	2.4%	1.6%	1.8%
Gas-fired instantaneous	9.6%	9.9%	7.4%	7.8%

Table 10. Hot water measures percent improvement for ERS-1048, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	2.5%	2.4%	2.0%	1.8%
Gas-fired instantaneous	9.9%	9.5%	7.1%	6.9%

For ERS-1073, Table 9 shows that under PCF 1819 there is a slight increase in percent improvement from the hot water measures compared to NBC 2020. This is due to hot water representing a larger portion of the regulated loads under PCF 1819, shown previously in Figure 9. Conversely, ERS-1048 obtains a slight decrease in percent improvement since, under PCF 1819, hot water loads account for a reduced portion of the total regulated load, shown previously in Figure 10. Again, the impact of PCF 1819 for these archetypes and this scenario are relatively small, with Tables 9 and 10 showing that across the climate zones and measures considered the percent improvement varies between 0.1 and 0.4% compared to 2020 NBC.

#### 4.1.1.1.2 Subsection 9.36.5 with Air Barrier Not Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.

If no airtightness test is performed for compliance with Subsection 9.36.5., and the air barrier *is not* constructed in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., both 2020 NBC and PCF 1819 require the proposed house be modelled with a reduced airtightness performance relative to its reference. This implies that other building component energy conservation measures are needed to comply. The archetypes and measures considered previously were re-evaluated for this scenario, and the reference and proposed airtightness

performance values required for modelling are in Table 11 for both 2020 NBC and PCF 1819 calculation procedures.

Table 11. Reference and proposed airtightness performance for no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Archetype	Reference ACH <sub>50</sub>		Proposed ACH <sub>50</sub>	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
ERS-1073	2.5	1.94	3.2	2.73
ERS-1048		3.43		4.82

The percent improvement of the above-grade wall measures under PCF 1819 and 2020 NBC for ERS-1073 and ERS-1048 are summarized in Tables 12 and 13, respectively.

Table 12. Wall measures percent improvement for ERS-1073, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> -K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-3.7%	-4.6%	-4.6%	-5.6%
3.51	-1.7%	-2.5%	-2.7%	-3.5%
3.85	2.0%	1.3%	1.2%	0.5%
4.23	3.7%	3.1%	3.0%	2.4%
4.59	5.5%	5.0%	4.9%	4.4%
4.89	6.7%	6.2%	6.1%	5.6%
5.22	7.9%	7.4%	7.4%	7.0%

Table 13. Wall measures percent improvement for ERS-1048, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> -K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-4.6%	-2.0%	-2.9%	-6.4%
3.51	-2.5%	-0.7%	-1.2%	-4.9%
3.85	1.3%	1.0%	0.5%	-3.1%
4.23	3.1%	2.5%	2.1%	-1.5%
4.59	5.0%	3.7%	3.4%	-0.4%
4.89	6.2%	4.5%	4.3%	0.6%
5.22	7.4%	5.4%	5.3%	1.4%

Tables 14 and 15 summarize the percent improvement from the hot water measures under PCF 1819 and 2020 NBC calculation requirements for ERS-1073 and ERS-1048, respectively.

Table 14. Hot water measures percent improvement for ERS-1073, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-2.8%	-3.7%	-4.6%	-5.5%
Gas-fired instantaneous	4.4%	4.0%	1.2%	0.6%

Table 15. Hot water measures percent improvement for ERS-1048, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-0.7%	-3.7%	-2.1%	-5.7%
Gas-fired instantaneous	6.7%	3.6%	3.2%	-0.6%

Compared to the previous scenario, the differences here between PCF 1819 and 2020 NBC are more complex. Not only does the reference and proposed models airtightness performance change, but the relative airtightness performance between them also changes. Under the 2020 NBC, the difference in airtightness performance ( $\Delta\text{ACH}_{50}$ ) for both archetypes are 0.7  $\text{ACH}_{50}$  (i.e., 3.2-2.5  $\text{ACH}_{50}$ ). Under PCF 1819,  $\Delta\text{ACH}_{50}$  for ERS-1073 is 0.79  $\text{ACH}_{50}$ , whereas for ERS-1048 it is 1.39  $\text{ACH}_{50}$ , determined from the reference and proposed model  $\text{ACH}_{50}$  values in Table 11. Therefore, compared to 2020 NBC there is a larger performance gap between the reference and proposed under PCF 1819 for both archetypes.

The  $A_e/V$  ratio at which PCF 1819 has a limited impact on compliance outcomes for this scenario would be the point at which  $\Delta\text{ACH}_{50}$  between reference and proposed is equal to 0.7  $\text{ACH}_{50}$ :

$$3.2 - 2.5 = 3.6 \cdot \left(\frac{A_e}{V}\right) \cdot 1.25 - 3.6 \cdot \left(\frac{A_e}{V}\right) \cdot 0.89 \rightarrow \left(\frac{A_e}{V}\right) = 0.540 \text{ m}^2/\text{m}^3 \quad (12)$$

The right-side of the expression is the difference of the equivalent  $\text{ACH}_{50}$  of the proposed and reference models, calculated using Equation (6) and the corresponding  $\text{NLR}_{50}$  performance values in PCF 1819. The left-side of the expression is the difference between proposed and reference airtightness performance under 2020 NBC. Equation (12) shows that detached buildings with an  $A_e/V$  of 0.540  $\text{m}^2/\text{m}^3$  will have a  $\Delta\text{ACH}_{50}$  of 0.7 under both 2020 NBC and PCF 1819 modelling requirements. Detached buildings with an  $A_e/V$  above 0.540  $\text{m}^2/\text{m}^3$  will have a greater  $\Delta\text{ACH}_{50}$  between reference and proposed, and therefore, a greater performance gap to overcome to comply with Subsection 9.36.5. Note that in Table 1 none of the 120 detached home new construction archetypes have a  $A_e/V$  at or below 0.540  $\text{m}^2/\text{m}^3$  (minimum is 0.547  $\text{m}^2/\text{m}^3$ ), and therefore, detached archetypes would require additional energy conservation measures to comply relative to 2020 NBC.

#### 4.1.1.1.3 Subsection 9.36.7 with Air Barrier Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.

Under 2020 NBC requirements, if the proposed building constructs its air barrier in accordance with Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., but elects not to use an airtightness test, the proposed building is required to be modelled with an airtightness performance of 3.2  $\text{ACH}_{50}$ . This is a deviation from Subsection 9.36.5. which allows the use of 2.5  $\text{ACH}_{50}$  in the proposed model if the air barrier is constructed to the extra prescriptive requirements. Mentioned in Section 2.5.2.1, this deviation was deliberate.

PCF 1819 proposes to align the proposed building model building infiltration simulation rules in Subsection 9.36.7. with 9.36.5., allowing buildings electing not to airtightness test, but have constructed their air barrier to the extra prescriptive requirements, to model the proposed house with the same  $0.89 \text{ L}/(\text{s}\cdot\text{m}^2) @ \Delta\text{P}=50 \text{ Pa}$  airtightness performance as the reference. Table 16 provides the reference and proposed model  $\text{ACH}_{50}$  performance for the detached archetypes under 2020 NBC and PCF 1819.

Table 16. Reference and proposed airtightness performance for no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.7.

Archetype	Reference $\text{ACH}_{50}$		Proposed $\text{ACH}_{50}$	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
ERS-1073	2.5	1.94	3.2	1.94
ERS-1048		3.43		3.43

It can be seen in Table 16 that under the 2020 NBC requirements there is an initial gap in airtightness performance between reference and proposed models that the proposed building model must overcome to first achieve Tier 1. PCF 1819 proposes to eliminate this initial gap.

As with the previous sections, the efficacy of above-grade wall and service hot water measures were evaluated under 2020 NBC and PCF 1819 requirements for this compliance scenario, and the results are summarized in Tables 17 to 20.

Table 17. Wall measures percent improvement for ERS-1073, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.7.

Wall Effective RSI [ $\text{m}^2\cdot\text{K}/\text{W}$ ]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-3.7%	1.5%	-4.6%	1.6%
3.51	-1.7%	3.6%	-2.7%	3.7%
3.85	2.0%	7.2%	1.2%	7.8%
4.23	3.7%	9.0%	3.0%	9.6%
4.59	5.5%	10.9%	4.9%	11.6%
4.89	6.7%	12.1%	6.1%	12.8%
5.22	7.9%	13.3%	7.4%	14.2%

Table 18. Wall measures percent improvement for ERS-1048, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.7.

Wall Effective RSI [ $\text{m}^2\cdot\text{K}/\text{W}$ ]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-4.6%	1.1%	-2.9%	1.1%
3.51	-2.5%	2.4%	-1.2%	2.6%
3.85	1.3%	4.0%	0.5%	4.4%
4.23	3.1%	5.5%	2.1%	5.9%
4.59	5.0%	6.6%	3.4%	7.1%
4.89	6.2%	7.4%	4.3%	8.0%
5.22	7.4%	8.2%	5.3%	8.9%

Table 19. Hot water measures percent improvement for ERS-1073, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.7.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-2.8%	2.4%	-4.6%	1.8%
Gas-fired instantaneous	4.4%	9.9%	1.2%	7.8%

Table 20. Hot water measures percent improvement for ERS-1048, no airtightness test and air barrier constructed with extra prescriptive measures Subsection 9.36.7.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-0.7%	2.4%	-2.1%	1.8%
Gas-fired instantaneous	6.7%	9.5%	3.2%	6.9%

Across both archetypes, both climates, and both measures, PCF 1819 increases the percent improvement calculated for the conservation measures, primarily due to the elimination of the airtightness performance gap in this compliance scenario, and not from the switch from ACH<sub>50</sub> to NLR<sub>50</sub>.

#### 4.1.1.1.4 Subsection 9.36.7 with Air Barrier Not Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.

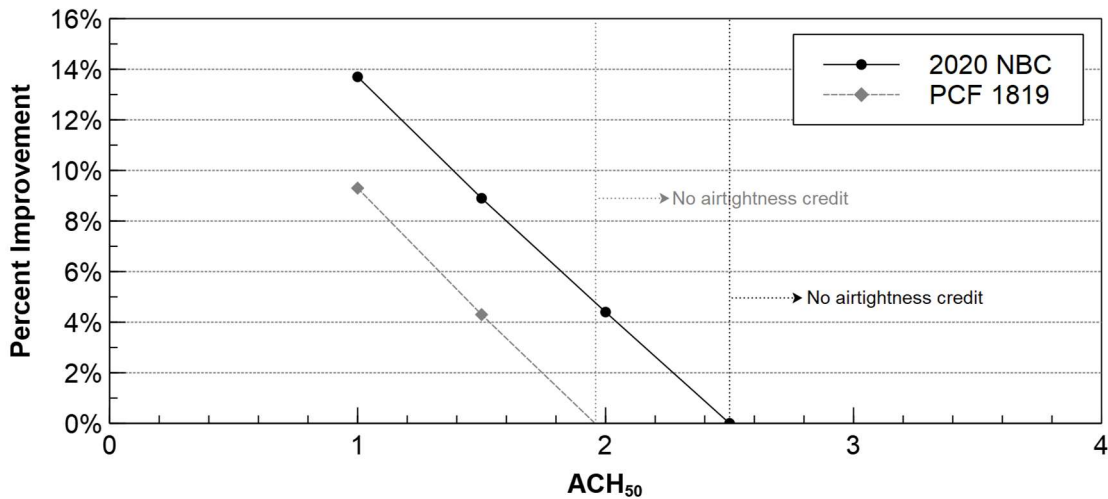
When seeking compliance under Subsection 9.36.7. for a detached home electing not to perform an airtightness test and not constructing its air barrier to the extra prescriptive requirements, the 2020 NBC requires that the proposed building be modelled with an airtightness performance of 3.2 ACH<sub>50</sub> and the reference with 2.5 ACH<sub>50</sub>. PCF 1819 replaces 3.2 ACH<sub>50</sub> with 1.25 L/(s·m<sup>2</sup>) @ ΔP=50 Pa and 2.5 ACH<sub>50</sub> with 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa; this scenario and the differences between 2020 NBC and PCF 1819 are identical to the one covered previously in Section 4.1.1.1.2. which showed that detached buildings with an  $A_e/V$  greater than 0.540 m<sup>2</sup>/m<sup>3</sup> will require additional measures to comply under PCF 1819 compared to 2020 NBC.

#### 4.1.1.2 Airtightness Test Performed

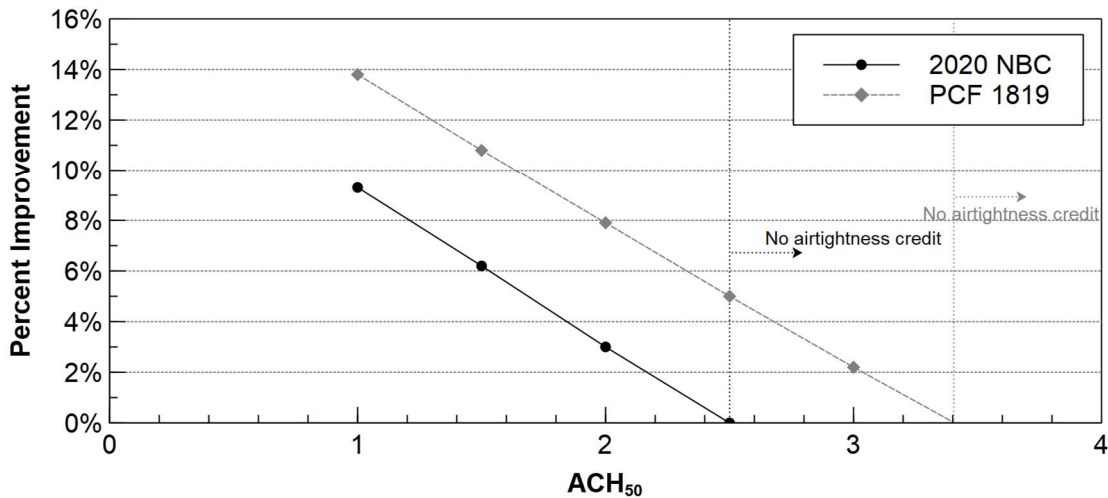
If an airtightness test is performed per Subsection 9.36.6. of the 2020 NBC, the measured performance value may be used as an input to the proposed building model. For detached buildings, PCF 1819 does not materially change how the proposed building is modelled; under both 2020 NBC and PCF 1819 requirements it is ultimately the total measured infiltration flow rate that is used as an input to the model. The impact of PCF 1819 arises from the change in the airtightness performance of the reference model. As it was shown previously in Table 4, depending on the  $A_e/V$  ratio of the building, the modelled infiltration in the reference building will either increase or decrease. Shown in Figure 2, for detached buildings the reference building airtightness performance changes from 2.5 ACH<sub>50</sub> to a NLR<sub>50</sub> of 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa under PCF 1819. Shown previously, using Equation (6) the  $A_e/V$  ratio at which there is no change to reference airtightness performance when adopting PCF 1819 (i.e., 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa equates to 2.5 ACH<sub>50</sub>) can be calculated ( $A_e/V_{critical}$ ) and is 0.780 m<sup>2</sup>/m<sup>3</sup>. What follows then is:

- If  $A_e/V > 0.780 \text{ m}^2/\text{m}^3$  then the reference building infiltration will increase;
- If  $A_e/V < 0.780 \text{ m}^2/\text{m}^3$  then the reference building infiltration will decrease.

To analyze the implications of this change under the performance path, the reference model of archetypes ERS-1073, which has an  $A_e/V$  of  $0.607 \text{ m}^2/\text{m}^3$ , and ERS-1048, which has an  $A_e/V$  of  $1.07$ , that were described previously in Section 4.1.1.1 of this report, were used. Like the previous analyses, proposed models were built upon the reference. Here, however, the only energy conservation measure considered was the airtightness performance which was varied between 3.5 and 1.0  $\text{ACH}_{50}$ . The percent improvement achieved from airtightness performance by the archetypes under both the 2020 NBC and PCF 1819 modelling requirements are plotted in Figure 11. Only Climate Zone 7A (Edmonton, AB) was considered.



a) ERS-1073,  $A_e/V = 0.607 \text{ m}^2/\text{m}^3$



b) ERS-1048,  $A_e/V = 1.07 \text{ m}^2/\text{m}^3$

Figure 11. Comparing airtightness test credits for detached homes under 2020 NBC and PCF 1819

Recall from Section 2.5.2.1 of this report that if the measured airtightness performance is less than the reference (i.e., a greater  $\text{ACH}_{50}$  value), then the reference  $\text{ACH}_{50}$  may be used in the proposed building instead. Thus, there are no negative percent improvement credits allocated if the measured airtightness underperforms relative to the reference. For archetype ERS-1073 with  $A_e/V$  ratio of  $0.607 \text{ m}^2/\text{m}^3$ , under 2020 NBC modelling requirements any  $\text{ACH}_{50}$  less than 2.5 will yield credit in the performance path, with 1.0  $\text{ACH}_{50}$  yielding a percent improvement

of 13.7%. Under PCF 1819, archetype ERS-1073 does not receive credit until it achieves an  $ACH_{50}$  below 1.94. At 1.0  $ACH_{50}$ ; the percent improvement credit is reduced to 9.3%.

Archetype ERS-1048, which has an  $A_e/V$  ratio of  $1.07 \text{ m}^2/\text{m}^3$ , also does not start to receive credit for airtightness performance until an  $ACH_{50}$  below 2.5 is achieved under 2020 NBC. At 1.0  $ACH_{50}$  ERS-1048 achieves a percent improvement of 9.3%. Under PCF 1819, credit for airtightness can start being allocated once  $ACH_{50}$  is below 3.43, and at 1.0  $ACH_{50}$  a percent improvement of 13.8% is credited. If a building has an  $A_e/V$  equal to  $A_e/V_{critical}$  then there will be no difference in outcomes if the compliance evaluation was done under 2020 NBC or PCF 1819 requirements since both procedures would use 2.5  $ACH_{50}$  in the reference.

#### 4.1.2 Attached Buildings

Per Figure 2(a), unless an unguarded airtightness test is performed, the reference model is assumed to have an airtightness performance of 2.5  $ACH_{50}$  (2020 NBC Sentence 9.36.5.14.(2)). If an unguarded test is performed *and used* in the proposed model, then the reference model assumes 3.0  $ACH_{50}$ . Figure 12 provides the 2020 NBC reference airtightness performance of the 120 detached archetypes, expressed in terms of  $NLR_{50}$ . Figure 12(a) provides the nominal  $NLR_{50}$  performance of the *exterior* air barrier (i.e.,  $A_e$ ), and is the reference used when a *guarded* airtightness test is conducted for performance-path compliance. Figure 12 (b) provides the nominal  $NLR_{50}$  performance of all bounding surfaces (exterior and surfaces separating the test zone from other attached zones,  $A_T$ ). This is the reference performance used when an *unguarded* airtightness test is conducted for compliance under the performance path. Like the data presented in Figure 6, the reference  $NLR_{50}$  values were back-calculated using Equation (6) and the  $A/V$  ratios in Figures 4 and 5.

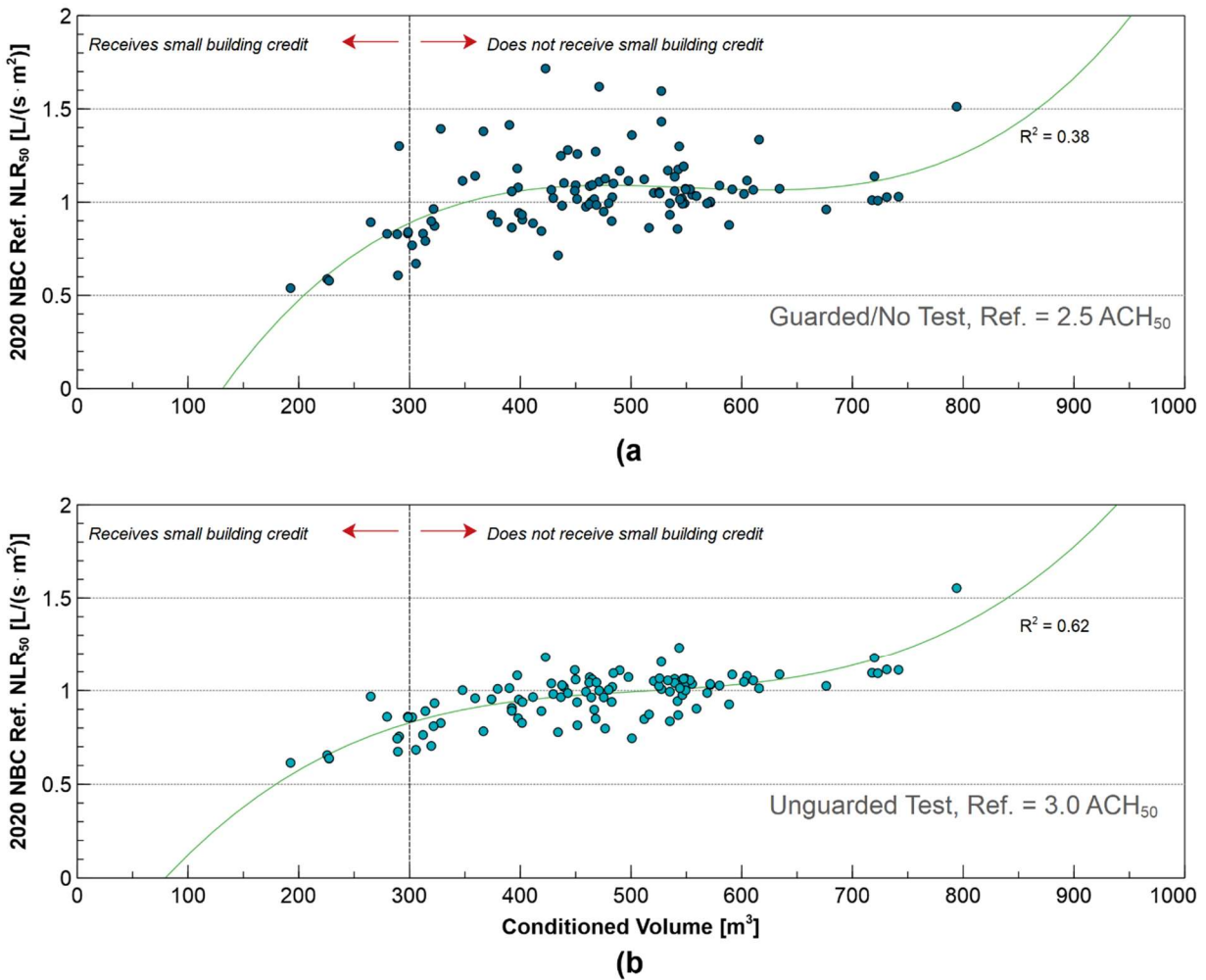


Figure 12. 2020 NBC equivalent  $NLR_{50}$  for reference model of attached archetypes

There is significantly more scatter for the reference  $NLR_{50}$  when a guarded test is used relative to the unguarded reference values, evident from the  $R^2$  values. The larger scatter for guarded  $NLR_{50}$  performance is driven by the higher variance of  $A_e/V$  ratios. Revisiting the  $A_e/V$  and  $A_T/V$  ratios of attached buildings presented previously in Figures 4 and 5, respectively, the variance<sup>2</sup> of  $A_e/V$  and  $A_T/V$  are 0.17 and 0.15 m<sup>2</sup>/m<sup>3</sup>, respectively. The  $A_e/V$  ratio for attached buildings is influenced by both geometry (e.g., aspect ratio) as well as degree of attachment. It can be shown using Equation (6) that as  $A_e/V$  decreases (i.e., the degree of attachment increases), the corresponding reference  $NLR_{50}$  under 2020 NBC increases. An increase in reference  $NLR_{50}$  is a relaxation since the reference building performance reduces.

Under PCF 1819, for both guarded and unguarded testing a reference  $NLR_{50}$  of 1.17 L/(s·m<sup>2</sup>) @  $\Delta P=50$  Pa is used for attached buildings, and that performance is only applied to the exterior areas ( $A_e$ ) for the purposes of

<sup>2</sup> Standard deviation

modelling under the performance path. The following subsections provide the results of the impact analyses conducted using the attached archetypes in Table 2.

#### 4.1.2.1 No Airtightness Test Performed

Like detached buildings, if no airtightness test is performed then both 2020 NBC and PCF 1819 prescribe default airtightness performance values for the proposed models. The following subsections provide the results of the impact analyses which analyzed the scenarios where attached archetypes seek compliance without airtightness testing.

##### 4.1.2.1.1 Subsection 9.36.5 with Air Barrier Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.

If no airtightness test is performed, and the air barrier was constructed per Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10., then under both 2020 NBC and PCF 1819 the reference and proposed models use the same airtightness performance, shown in Table 21.

Table 21. Reference and proposed airtightness performance for no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Archetype	Reference ACH <sub>50</sub>		Proposed ACH <sub>50</sub>	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
ERS-4875	2.5	2.29	2.5	2.29
ERS-3060		3.30		3.30

The  $A_e/V$  ratio at which the reference and proposed models would use the same airtightness performance under both 2020 NBC and PCF 1819 ( $A_e/V_{critical}$ ) is 0.593 m<sup>2</sup>/m<sup>3</sup> for this compliance scenario. Attached buildings with an  $A_e/V$  greater than 0.593 m<sup>2</sup>/m<sup>3</sup> will have a higher ACH<sub>50</sub> (lower performance), and buildings with an  $A_e/V$  lower than 0.593 m<sup>2</sup>/m<sup>3</sup> will have a lower ACH<sub>50</sub> (higher performance), relative to 2020 NBC.

As with the detached archetypes, the performance savings from above-grade wall and service hot water measures were evaluated under both 2020 NBC and PCF 1819 modelling requirements, and the results are summarized in Tables 22 to 25.

Table 22. Wall measures percent improvement for ERS-4875, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> -K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	0.8%	1.1%	1.1%	1.1%
3.51	2.3%	2.4%	2.5%	2.4%
3.85	4.2%	4.3%	4.6%	4.5%
4.23	5.5%	5.6%	5.8%	6.0%
4.59	6.5%	6.7%	7.1%	7.1%
4.89	7.4%	7.5%	7.9%	8.1%
5.22	8.2%	8.4%	8.7%	8.9%

Table 23. Wall measures percent improvement for ERS-3060, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> ·K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	1.3%	1.0%	1.3%	1.2%
3.51	2.7%	2.6%	2.8%	2.7%
3.85	5.7%	5.4%	5.9%	5.6%
4.23	7.1%	6.8%	7.3%	7.1%
4.59	8.6%	8.2%	8.9%	8.6%
4.89	9.7%	9.2%	9.8%	9.4%
5.22	10.7%	10.2%	10.9%	10.3%

Table 24. Hot water measures percent improvement for ERS-4875, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	3.2%	3.2%	2.4%	2.3%
Gas-fired instantaneous	12.2%	12.5%	8.5%	8.5%

Table 25. Hot water measures percent improvement for ERS-3060, no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	3.4%	3.2%	2.2%	2.1%
Gas-fired instantaneous	14.1%	13.2%	8.9%	8.4%

The results in Tables 22 to 25 are similar to those seen previously for the detached archetypes in Section 4.1.1.1 of this report; the percent savings from the measures are reduced under PCF 1819 for buildings with a relatively large  $A_e/V$  ratio (ERS-3060), whereas the percent savings from all other measures besides airtightness are increased under PCF 1819 for buildings with a relatively small  $A_e/V$  ratio (ERS-4875). For the measures, climates, and archetypes considered in Tables 22 to 25, the change in percent savings varies between 0 and 0.9%.

#### 4.1.2.1.2 Subsection 9.36.5 with Air Barrier Not Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.

If there is no airtightness test conducted, the building is attached, and the air barrier is *not* constructed to the extra prescriptive requirements, then per Figure 2 the reference building uses an airtightness performance of 2.5 ACH<sub>50</sub> and 1.17 L/(s·m<sup>2</sup>) @ ΔP=50 Pa under 2020 NBC and PCF 1819, respectively. Per Figure 3 the proposed building uses 3.2 ACH<sub>50</sub> and 1.25 L/(s·m<sup>2</sup>) @ ΔP=50 Pa under 2020 NBC and PCF 1819, respectively. The reference and proposed archetype infiltration inputs for this scenario are summarized in Table 26.

Table 26. Reference and proposed airtightness performance for no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Archetype	Reference ACH <sub>50</sub>		Proposed ACH <sub>50</sub>	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
ERS-4875	2.5	2.29	3.2	2.44
ERS-3060		3.30		3.52

Tables 27 to 30 summarize the results for this scenario.

Table 27. Wall measures percent improvement for ERS-4875, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> ·K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-5.3%	-0.4%	-6.3%	-0.6%
3.51	-3.8%	0.9%	-4.9%	0.8%
3.85	-1.9%	2.8%	-2.8%	2.9%
4.23	-0.6%	4.1%	-1.4%	4.2%
4.59	0.6%	5.4%	-0.2%	5.5%
4.89	1.3%	6.0%	0.6%	6.3%
5.22	2.1%	6.9%	1.4%	7.1%

Table 28. Wall measures percent improvement for ERS-3060, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> ·K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-3.2%	-0.2%	-3.9%	-0.4%
3.51	-1.5%	1.2%	-2.2%	1.2%
3.85	1.5%	4.2%	0.9%	4.1%
4.23	2.9%	5.6%	2.3%	5.5%
4.59	4.4%	7.0%	3.9%	6.9%
4.89	5.5%	7.8%	4.8%	7.8%
5.22	6.3%	8.8%	5.9%	8.9%

Table 29. Hot water measures percent improvement for ERS-4875, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-3.0%	1.9%	-5.2%	0.5%
Gas-fired instantaneous	6.3%	11.2%	1.4%	6.9%

Table 30. Hot water measures percent improvement for ERS-3060, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-0.8%	1.8%	-3.0%	0.4%
Gas-fired instantaneous	9.7%	12.0%	3.9%	6.9%

It can be seen that under PCF 1819 the above-grade walls and service hot water measures yield more calculated percent improvement for both archetypes compared to 2020 NBC. Conversely, for the detached archetypes when no airtightness test is done and the air barrier is not constructed to extra prescriptive requirements, PCF 1819 reduces the calculated savings of these measures, shown previously in Section 4.1.1.1.2 of this report. The reason for the discrepancy is due to how PCF 1819 explicitly treats attached and detached buildings differently. Under 2020 NBC, if a building does not perform an airtightness test, and the air barrier is not constructed to the extra prescriptive requirements, then the reference model has an airtightness performance of 2.5 ACH<sub>50</sub> and the proposed has 3.2 ACH<sub>50</sub>, regardless of attachment type. Under PCF 1819, the reference for attached buildings have a lower airtightness performance compared to detached (1.17 versus 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa), but for both attached and detached the proposed building uses 1.25 L/(s·m<sup>2</sup>) @ ΔP=50 Pa.

Using a similar approach as Equation (12), the critical  $A_e/V$  ratio ( $A_e/V_{critical}$ ) for which both 2020 NBC and PCF 1819 calculation approaches yield the same airtightness performance gap, or “difference”, in this compliance scenario is 2.43 m<sup>2</sup>/m<sup>3</sup>. Any attached building with an  $A_e/V$  less than 2.43 m<sup>2</sup>/m<sup>3</sup> will have a smaller airtightness performance gap and therefore receive a relaxation under PCF 1819. Per Table 1, the maximum attached new construction archetype  $A_e/V$  ratio is 1.29 m<sup>2</sup>/m<sup>3</sup>; thus, all attached archetypes receive a relaxation under PCF 1819 for this scenario.

#### 4.1.2.1.3 Subsection 9.36.7 with Air Barrier Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.

Like the detached archetypes in Section 4.1.1.1.3 of this report, if an attached building constructs its air barrier to the extra prescriptive requirements and does not perform an airtightness test, the 2020 NBC does not allow the use of the higher airtightness performance that is permitted in Subsection 9.36.5. Sentence 9.36.7.3.(9) directs the code user to use 3.2 ACH<sub>50</sub> in the proposed model, with 2.5 ACH<sub>50</sub> in the reference. PCF 1819 allows an assumed increase in proposed building airtightness performance if the building is constructed with the extra air barrier requirements. The reference and proposed model ACH<sub>50</sub> performance inputs under 2020 NBC and PCF 1819 for the attached archetypes under this scenario are provided in Table 31.

Table 31. Reference and proposed airtightness performance for no airtightness test and air barrier constructed with extra prescriptive measures under Subsection 9.36.7.

Archetype	Reference ACH <sub>50</sub>		Proposed ACH <sub>50</sub>	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
ERS-4875	2.5	2.29	3.2	2.29
ERS-3060		3.30		3.30

Tables 32 to 35 summarize the percent improvement of above-grade wall and service hot water measures applied to the attached archetypes, calculated under 2020 NBC and PCF 1819 modelling requirements.

Table 32. Wall measures percent improvement for ERS-4875, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> ·K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-5.3%	1.1%	-6.3%	1.1%
3.51	-3.8%	2.4%	-4.9%	2.4%
3.85	-1.9%	4.3%	-2.8%	4.5%
4.23	-0.6%	5.6%	-1.4%	6.0%
4.59	0.6%	6.7%	-0.2%	7.1%
4.89	1.3%	7.5%	0.6%	8.1%
5.22	2.1%	8.4%	1.4%	8.9%

Table 33. Wall measures percent improvement for ERS-3060, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Wall Effective RSI [m <sup>2</sup> ·K/W]	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
3.25	-3.2%	1.0%	-3.9%	1.2%
3.51	-1.5%	2.6%	-2.2%	2.7%
3.85	1.5%	5.4%	0.9%	5.6%
4.23	2.9%	6.8%	2.3%	7.1%
4.59	4.4%	8.2%	3.9%	8.6%
4.89	5.5%	9.2%	4.8%	9.4%
5.22	6.3%	10.2%	5.9%	10.3%

Table 34. Hot water measures percent improvement for ERS-4875, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-3.0%	3.2%	-5.2%	2.3%
Gas-fired instantaneous	6.3%	12.5%	1.4%	8.5%

Table 35. Hot water measures percent improvement for ERS-3060, no airtightness test and air barrier not constructed with extra prescriptive measures under Subsection 9.36.5.

Service Hot Water System	Climate Zone 5		Climate Zone 7A	
	2020 NBC	PCF 1819	2020 NBC	PCF 1819
Gas hot water with powervent tank	-0.8%	3.2%	-3.0%	2.1%
Gas-fired instantaneous	9.7%	13.2%	3.9%	8.4%

Similar to the detached building results in Section 4.1.1.1.3 of this report, when no airtightness testing is done for an attached building and the air barrier was constructed with the extra prescriptive requirements PCF 1819 will yield greater calculated percent improvement from energy conservation measures relative to 2020 NBC; i.e., less energy conservation measures are needed to meet the same Tier if PCF 1819 is adopted compared to 2020 NBC. This impact is primarily driven from allowing the reference and proposed model to use the same airtightness performance under PCF 1819, whereas under 2020 NBC if no airtightness testing is done the proposed model must use a lower airtightness performance relative to the reference model.

#### 4.1.2.1.4 Subsection 9.36.7 with Air Barrier Not Constructed to 9.25.3., 9.36.2.9. and 9.36.2.10.

This scenario is identical to the scenario described previously in Section 4.1.2.1.2 of this report. For the attached archetypes considered PCF 1819 would yield more credit for energy conservation measures compared to 2020 NBC; i.e., less energy conservation measures would need to be implemented to achieve the same level of compliance if PCF 1819 is adopted.

### 4.1.2.2 Airtightness Test Performed

There are two possible scenarios to consider when an airtightness test is performed under the performance path and the building is attached: whether the test was guarded or unguarded. The two tests were briefly described in Section 2.2 of this report, and the choice of test type influences the modelling in the performance path. The reference building airtightness performance inputs under 2020 NBC and PCF 1819 for the two attached archetypes are summarized in Table 36.

Table 36. Changes to the reference model ACH<sub>50</sub>: Attached buildings, airtightness test performed

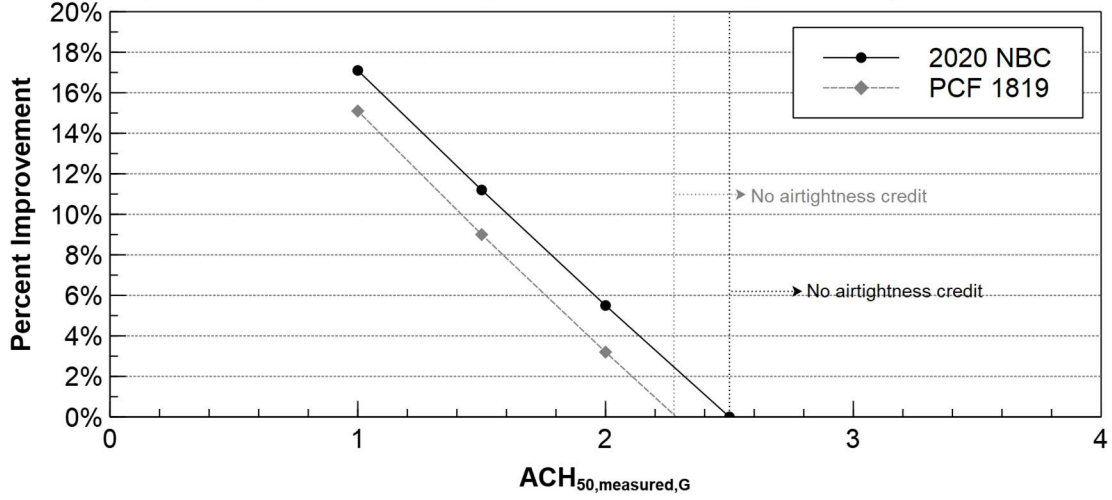
Archetype	Storeys	Floor Area [ft <sup>2</sup> ]	Conditioned Volume [m <sup>3</sup> ]	$A_e/V$ [m <sup>2</sup> /m <sup>3</sup> ]	$A_T/V$ [m <sup>2</sup> /m <sup>3</sup> ]	Reference Model ACH <sub>50</sub>		
						2020 NBC		PCF 1819
						Unguarded	Guarded	
ERS-4875	2	1680	443	0.543	0.844	3.0	2.5	2.29
ERS-3060	2	1670	410	0.783	0.868			3.30

It can be seen that under 2020 NBC requirements, the reference model ACH<sub>50</sub> varies based on test type, whereas under PCF 1819, the same airtightness performance is used in the reference model regardless of test type. The results of the impact analysis of PCF 1819 on performance path compliance outcomes when airtightness testing is used for attached buildings are provided in the following subsections. Only Climate Zone 7A (Edmonton, AB) was considered.

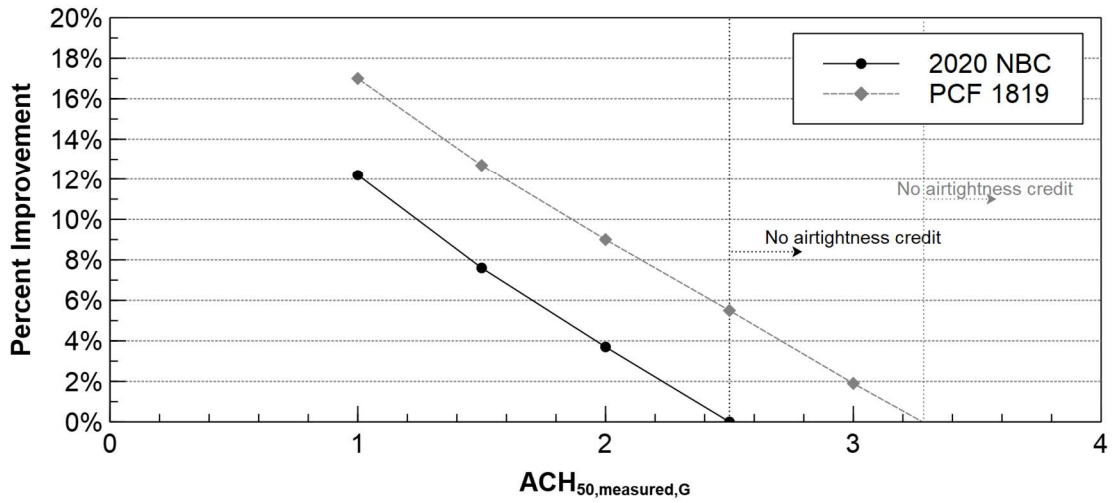
#### 4.1.2.2.1 Guarded Test

Using Equation (6), an  $A_e/V_{critical}$  value can be determined where a building having that ratio yields no change to the reference building airtightness performance relative to 2020 NBC. For guarded tests of attached buildings,  $A_e/V_{critical}$  is 0.593 m<sup>2</sup>/m<sup>3</sup>. Below  $A_e/V_{critical}$  the reference building will have a higher airtightness performance (smaller ACH<sub>50</sub>) under PCF 1819 compared to 2020 NBC, and above  $A_e/V_{critical}$  the reference building will have a lower airtightness performance (higher ACH<sub>50</sub>). The impact to calculated energy savings from guarded airtightness testing was assessed using archetypes ERS-4875 and ERS-3060 which have relatively low and high  $A_e/V$  ratios, respectively. This analysis used the same approach that was used previously in Section 4.1.1.2 of this report.

The change to percent improvement credits for guarded tests under the performance path are summarized in

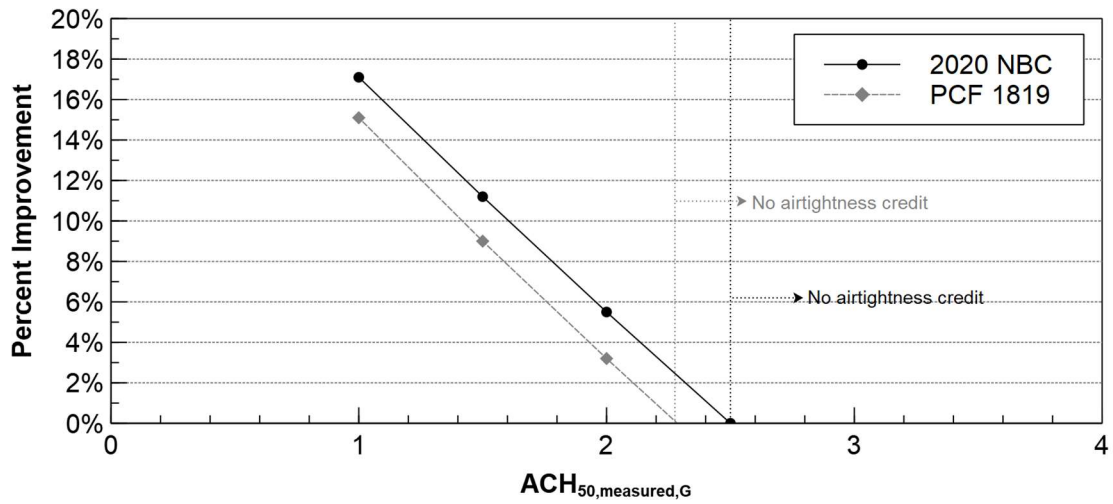


a) ERS-4875,  $A_e / V = 0.543 \text{ m}^2/\text{m}^3$

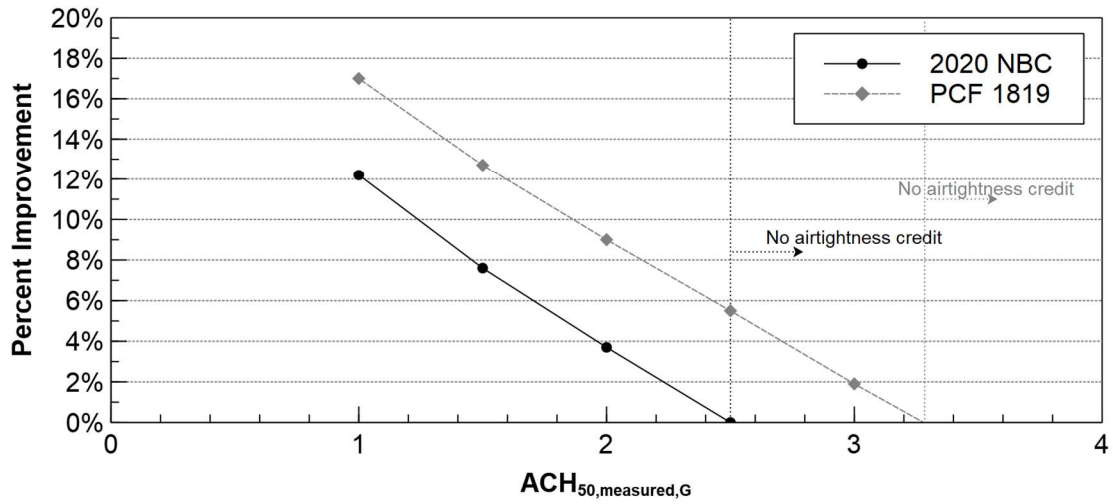


b) ERS-3060,  $A_e / V = 0.783 \text{ m}^2/\text{m}^3$

Figure 13. The  $ACH_{50}$  values are measured “guarded” values ( $ACH_{50,measured,G}$ ).



a) ERS-4875,  $A_e / V = 0.543 \text{ m}^2/\text{m}^3$



b) ERS-3060,  $A_e / V = 0.783 \text{ m}^2/\text{m}^3$

Figure 13. Comparing guarded airtightness test credits for attached homes under 2020 NBC and PCF 1819

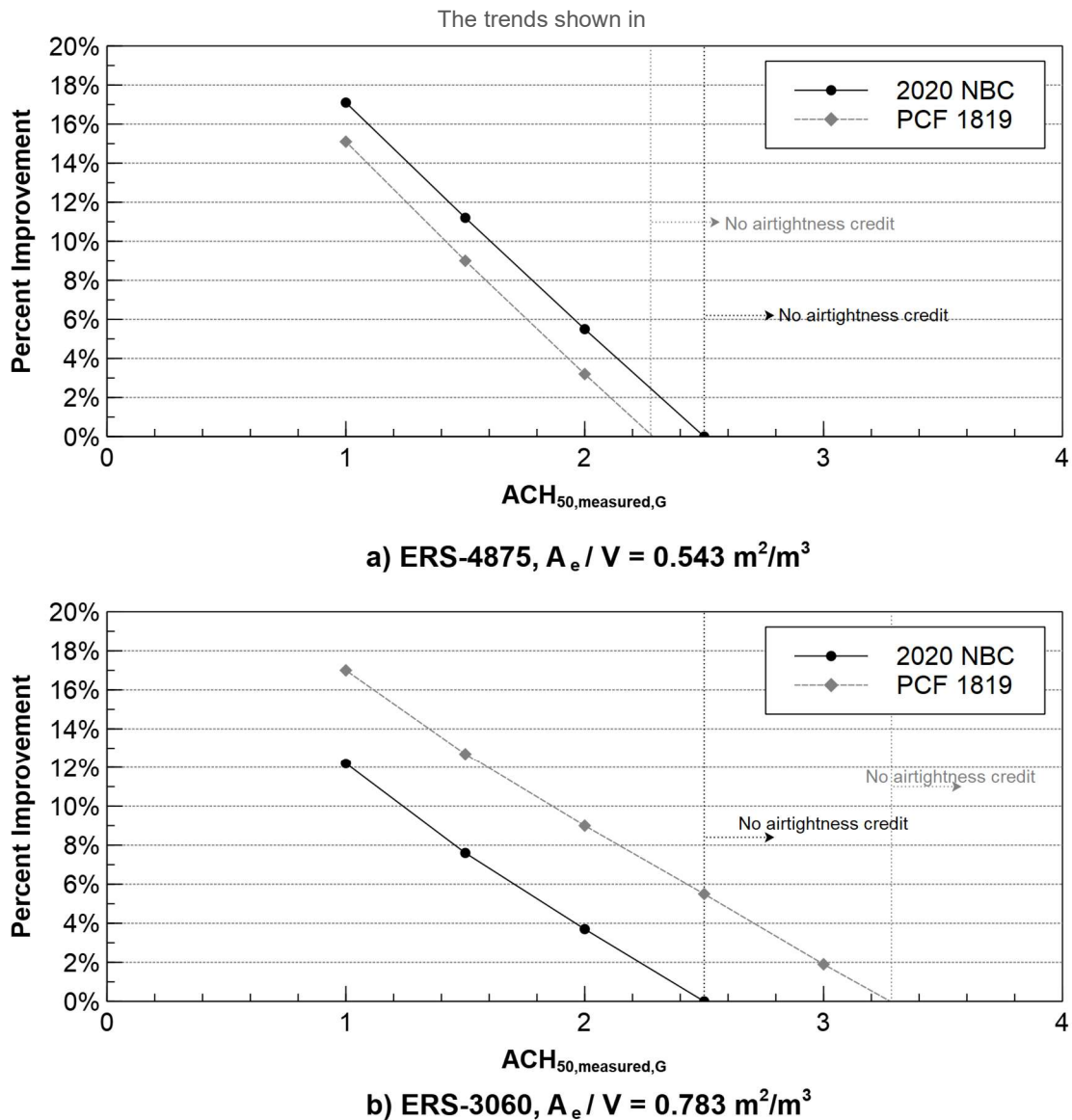


Figure 13 are similar to the detached houses shown previously in Figure 11. Archetype ERS-4785 has an  $A_e/V$  ratio below  $A_e/V_{critical}$ , and therefore, under PCF 1819, achieves smaller calculated energy savings for guarded airtightness testing under the performance path compared to 2020 NBC requirements. Conversely, archetype ERS-3060 which has an  $A_e/V$  ratio above  $A_e/V_{critical}$ , achieves higher calculated energy savings for airtightness performance under PCF 1819 compared to 2020 NBC modelling requirements.

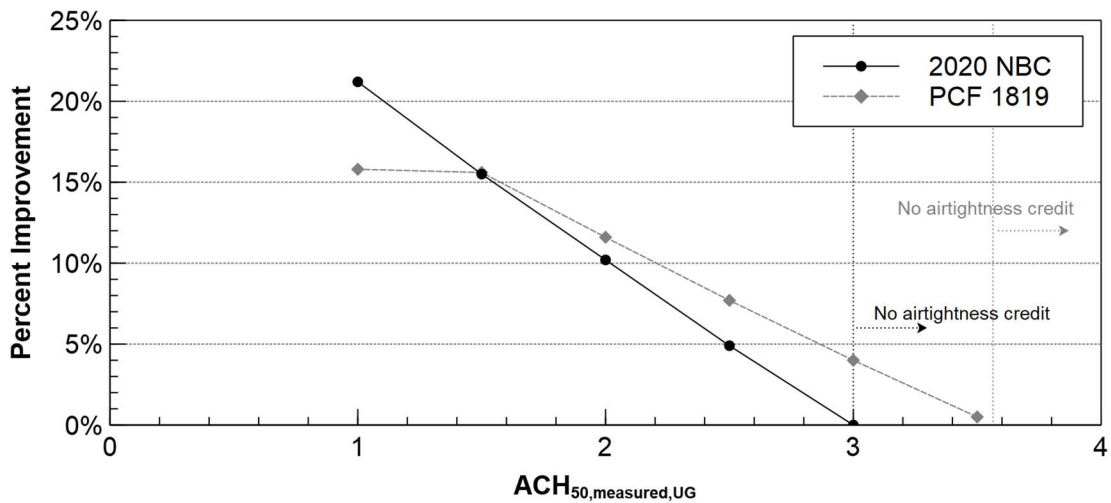
**4.1.2.2.2 Unguarded Test**

For the impact analysis under this scenario, unguarded  $ACH_{50}$  ( $ACH_{50,measured,UG}$ ) was varied between 3.5 and 0.6  $ACH_{50}$ . To perform the compliance calculations under 2020 NBC  $ACH_{50,measured,UG}$  is used directly in the proposed building model ( $ACH_{50,model}$ ), and the reference model uses 3.0  $ACH_{50}$ . Under PCF 1819  $ACH_{50,model}$  for the proposed model is determined using Equation (11) in Section 3.4 of this report, and Equation (10) (Section 2.5.2 of this report) is used to determine the reference model  $ACH_{50,model}$ . Table 37 provides the corresponding proposed model  $ACH_{50,model}$  values used for each archetype and  $ACH_{50,measured,UG}$  for PCF 1819 performance path calculations.

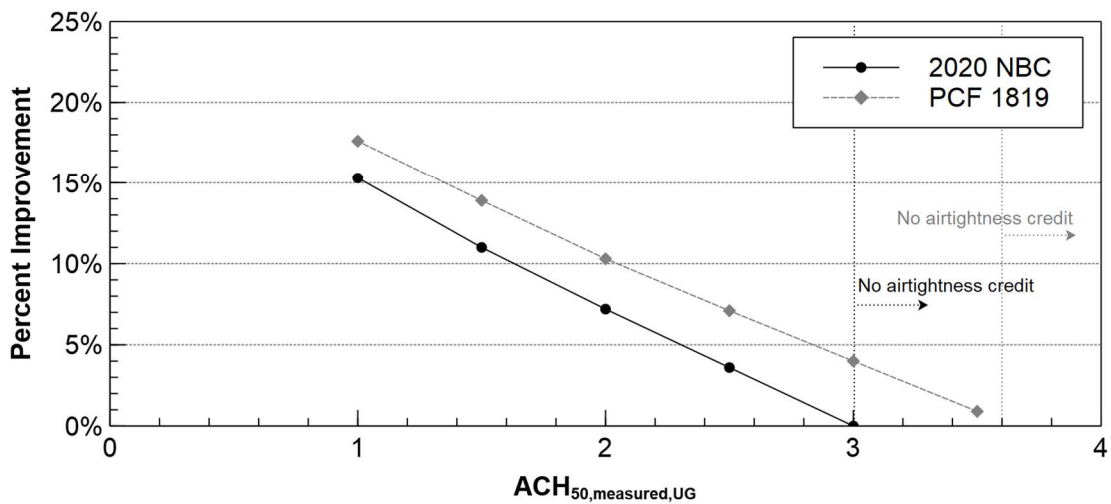
Table 37. Attached archetype proposed building airtightness performance inputs for unguarded measurements under PCF 1819

$ACH_{50,measured,UG}$	ERS-4875 $ACH_{50,model}$	ERS-3060 $ACH_{50,model}$
3.5	2.2	3.2
3.0	1.9	2.7
2.5	1.6	2.3
2.0	1.3	1.8
1.5	1.0	1.4
1.0	0.6	0.9

The calculated percent improvement per unguarded  $ACH_{50}$  measurements calculated under 2020 NBC and PCF 1819 modelling requirements for the attached archetypes are provided in Figure 14.



a) ERS-4875,  $A_T / V = 0.844 \text{ m}^2/\text{m}^3$



b) ERS-3060,  $A_T / V = 0.868 \text{ m}^2/\text{m}^3$

Figure 14. Comparing unguarded airtightness test credits for attached homes under 2020 NBC and PCF 1819

It can be seen that generally both archetypes achieve greater percent improvement credit under PCF 1819 modelling rules compared to 2020 NBC. Interestingly, ERS-4875 achieves a lower percent improvement at an unguarded  $ACH_{50}$  of 1.0 under PCF 1819 compared to 2020 NBC. Through close inspection of the model, this seems to be related to the modelled gas-furnace and service hot water system flue leakage. At an  $ACH_{50,measured,UG}$  of 1.0  $ACH_{50}$ ,  $ACH_{50,model}$  is 0.6  $ACH_{50}$  (shown in Table 37) and a corresponding input  $ELA_{10}$  of  $101 \text{ cm}^2$  is needed to achieve a flow exponent of 0.67; however, the combined flue cross-sectional area is  $172 \text{ cm}^2$ . The results in Figure 14(a) suggest that the input flue area over-rides the input  $ELA_{10}$  in the HOT2000 air leakage model leading to a *decrease* in performance improvement even though airtightness performance at  $\Delta P=50 \text{ Pa}$  is increasing. Future work will investigate this further, but for the current study, the data point at 1.0  $ACH_{50}$  in Figure 14(a) is ignored, the other data points are shown to be linear and generally achieve greater percent improvement under PCF 1819.

Like previous scenarios, a critical geometric ratio,  $A_T/V_{critical}$ , can be defined at which the modelling rules of both 2020 NBC and PCF 1819 yield the same or similar compliance outcomes. For unguarded testing of attached homes, the point at which no penalty or credit is allocated for airtightness is when the reference and proposed models have the same airtightness performance. In the 2020 NBC this may be expressed as:

$$ACH_{50,measured,UG} = ACH_{50,ref} \quad (13)$$

where  $ACH_{50,ref}$  is 3.0  $ACH_{50}$ . For PCF 1819, the point at which an unguarded  $ACH_{50}$  measurements yields no penalty or credit can be expressed as:

$$\left(\frac{A_e}{A_T}\right) \cdot ACH_{50,measured,UG} = 3.6 \cdot \left(\frac{A_e}{V}\right) \cdot 1.17 \quad (14)$$

where the left-side of the expression is from Equation (11) and represents the proposed model airtightness performance input, and the right-side is from Equation (6) representing the reference model performance ( $1.17 \text{ L}/(\text{s}\cdot\text{m}^2)$  @  $\Delta P=50 \text{ Pa}$ ). For PCF 1819 to have no impact on code compliance outcomes,  $ACH_{50,measured,UG}$  must be equal to 3.0  $ACH_{50}$  in Equation (14), and the right-side of Equation (14) must then also equal 3.0  $ACH_{50}$ . This can only occur if  $A_e/A_T$  is equal to 1 (i.e., a detached building). Since  $A_e/A_T$  is always less than 1 (and greater than 0) for all attached buildings, there will always be some variation in performance outcomes in this scenario compared to 2020 NBC. (Recall from Section 4.1.1.1.1 of this report that even though a reference and proposed model both use the same airtightness performance, if the magnitude of the performance changes, then the relative performance calculated for energy conservation measures shifts slightly).

Equation (14) can be rearranged to solve for the value of  $ACH_{50,UG}$  at which no airtightness credit is provided under PCF 1819:

$$ACH_{50,measured,UG} = 4.212 \cdot \left(\frac{A_T}{V}\right) \quad (15)$$

Setting  $ACH_{50,measured,UG}$  to 3.0  $ACH_{50}$ , the value of  $A_T/V_{critical}$  is  $0.712 \text{ m}^2/\text{m}^3$ . Buildings that have a  $A_T/V$  above  $A_T/V_{critical}$  will be able to begin obtaining airtightness credits at lower unguarded airtightness performance (i.e., higher  $ACH_{50,measured,UG}$  values) compared to 2020 NBC. Conversely, buildings that have a  $A_T/V$  below  $A_T/V_{critical}$  will require higher unguarded airtightness performance (i.e., lower  $ACH_{50,measured,UG}$  values) to begin obtaining credit in the performance path compared to 2020 NBC. Using the  $A_T/V$  estimates for the 120 attached archetypes, 96.7% of the archetypes receive a relaxation under PCF 1819; i.e., they would receive more credit for a given airtightness performance, and begin receiving credit at a lower performance compared to 2020 NBC.

Another challenge of analyzing the changes in PCF 1819 is the determination of the appropriate input for equivalent leakage area @  $\Delta P=10 \text{ Pa}$  ( $ELA_{10}$ ) when unguarded test data is used for proposed building modelling.

Equations (7) and (8) in this report showed that for HOT2000 both  $ACH_{50}$  and  $ELA_{10}$  are used as inputs to determine the measured airtightness performance curve. PCF 1819 provides Equation (10) to determine the  $ACH_{50}$  input for the proposed house, but how  $ELA_{10}$  is pre-processed for input to the model is unclear in the PCF. The PCF directs the code user to use  $A_e$  to determine  $ELA_{10}$ , however,  $ELA_{10}$  is not a normalized metric, it is an absolute area in  $cm^2$  and the approach of de-normalizing using  $A_e$  cannot be used.

If  $ACH_{50,model}$  is input into the proposed model with the  $ELA_{10}$  determined directly from the unguarded test, there is a possibility the simulation software will notify the user of an error and terminate the calculation. To illustrate, consider the case where an attached building has an internal volume of  $450\text{ m}^3$ ,  $A_e$  of  $270\text{ m}^2$ , and  $A_T$  of  $380\text{ m}^2$ . If an unguarded  $ACH_{50}$  of 2.0 is achieved with an  $ELA_{10}$  of  $341\text{ cm}^2$ , using Equation (7) the flow exponent  $n$  is 0.67. PCF 1819 directs the code user to determine  $ACH_{50,model}$  for input to the proposed building which for this example equates to 1.42  $ACH_{50}$ . If 1.42  $ACH_{50}$  is input with the measured  $ELA_{10}$  the resulting flow exponent calculated by the software is 0.46, which is outside the valid range for  $n$  and error will be passed to the user and the calculation will terminate. To preserve the same flow exponent that was determined during the test, the user must apply the following transformation to the measured  $ELA_{10}$ :

$$ELA_{10,model} = \left(\frac{A_e}{A_T}\right) \cdot ELA_{10,UG} \quad (16)$$

where  $ELA_{10,UG}$  is the measured  $ELA_{10}$  for the unguarded test [ $cm^2$ ], and  $ELA_{10,model}$  is the required input to the model. Equation (16) is not provided in the PCF submitted to public review.

## 4.2 Changes to Compliance in the Prescriptive Path

Under the 2020 NBC there are no mandatory requirements to perform an airtightness test for prescriptive compliance. However, under the Tiered Energy Compliance Prescriptive Path in Subsection 9.36.8. of the 2020 NBC, Table 9.36.8.8., a builder may optionally perform an airtightness test per Subsection 9.36.6. and obtain energy conservation points towards compliance. Points are allocated per airtightness level, and in the 2020 NBC airtightness levels are defined using  $ACH_{50}$ ,  $NLR_{50}$ , and  $NLA_{10}$  in Tables 9.36.6.4.-A and B; any one of the metrics may be used to determine airtightness level. PCF 1819 proposes to remove  $ACH_{50}$  as metric to determine airtightness level in Tables 9.36.6.4.-A and B., which define the airtightness levels per detached/guarded and unguarded test data, respectively.

By eliminating  $ACH_{50}$  for detached homes and attached homes using unguarded testing, PCF 1819 will require higher airtightness performance for buildings with  $A_e/V$  ratios below the  $A_e/V_{critical}$  values summarized in Table 38.

Table 38.  $A_e/V_{critical}$  values for Table 9.36.6.4.-A

Airtightness Level	$A_e/V_{critical}$ [ $m^2/m^3$ ]	Fraction of Archetypes Needing to Achieve Higher Performance under PCF 1819	
		120 Detached Archetypes	120 Attached Archetypes
AL-1A	0.780	60%	79%
AL-2A	0.782	60%	79%
AL-3A	0.786	64%	80%
AL-4A	0.794	67%	81%
AL-5A	0.794	67%	81%

For example, if a building has an  $A_e/V$  of  $0.60\text{ m}^2/m^3$ , to achieve AL-1A under PCF 1819 ( $0.89\text{ L}/(\text{s}\cdot\text{m}^2)$  @  $\Delta P = 50\text{ Pa}$ ) it will need to achieve an equivalent 1.92  $ACH_{50}$  (calculated using Equation (6)), whereas under 2020

NBC it can achieve AL-1A with 2.5 ACH<sub>50</sub>. To achieve AL-5A (0.21 L/(s·m<sup>2</sup>) @ ΔP = 50 Pa) it will need to achieve an equivalent of 0.45 ACH<sub>50</sub> compared to 0.6 ACH<sub>50</sub> under 2020 NBC. For buildings with  $A_e/V > A_e/V_{critical}$  there is no material change for compliance. For example, if a building has an  $A_e/V$  of 0.80 m<sup>2</sup>/m<sup>3</sup>, using NLR<sub>50</sub> instead of ACH<sub>50</sub> to comply with an airtightness level would be the easier path to compliance. At AL-1A, the NLR<sub>50</sub> requirement is 0.89 L/(s·m<sup>2</sup>) @ ΔP=50 Pa which for a building with an  $A_e/V$  of 0.80 m<sup>2</sup>/m<sup>3</sup> equates to an ACH<sub>50</sub> performance of 2.56 which is above the ACH<sub>50</sub> limit for AL-1A; therefore, the code user would select the NLR<sub>50</sub> metric for compliance.

Table 38 shows that 60 to 67% of the detached archetypes would need to achieve higher airtightness performance to maintain their current airtightness levels, and 79 to 81% of the attached archetypes would need achieve higher performance if PCF 1819 is adopted and guarded testing is performed.

For unguarded tests, the  $A_T/V$  ratio must be used instead of  $A_e/V$ , since  $A_T$  is the required normalizing area to determine NLR<sub>50</sub> per CGSB 149.10-2019. PCF 1819 will require higher airtightness performance for buildings with  $A_T/V$  ratios below the  $A_T/V_{critical}$  values summarized in Table 39.

Table 39.  $A_T/V_{critical}$  values for Table 9.36.6.4.-B

Airtightness Level	$A_T/V_{critical}$ [m <sup>2</sup> /m <sup>3</sup> ]	Fraction of Attached Archetypes Needing to Achieve Higher Performance under PCF 1819
AL-1B	0.712	3%
AL-2B	0.709	3%
AL-3B	0.712	3%
AL-4B	0.706	3%
AL-5B	0.712	3%
AL-6B	0.725	4%

Using the total area ( $A_T$ ) estimates of the 120 attached archetypes provided from NRCan OEE, adoption of PCF 1819 would have a limited impact on those archetypes; 3 to 4% of the 120 archetypes would need to achieve a higher airtightness performance to maintain current airtightness levels.

### 4.3 Tier 3 Case Study

This section provides the results of the case study described previously in Section 3.4 of this report. Figure 15 plots the distributions of the calculated percent improvement and percent heat loss reduction of the 2020 NBC Tier 3 packages developed for the 240 new construction archetypes. The climate zone used to develop the packages was 7A (Edmonton, AB). All packages achieved a peak cooling savings greater than zero relative to their reference buildings. It is important to note that Tier 3 solutions were not found for two detached archetypes with conditioned volumes greater than 300 m<sup>3</sup>, and one detached archetype with a conditioned volume less than 300 m<sup>3</sup>, and were therefore omitted from the results analysis.

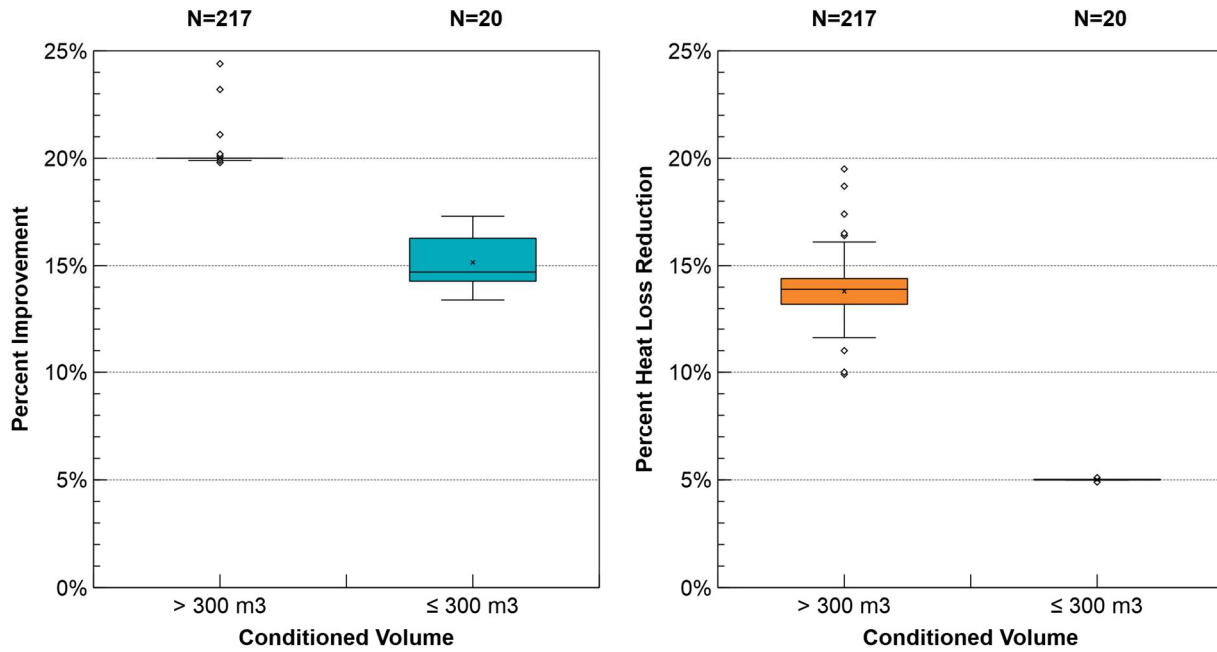


Figure 15. Percent improvement and percent heat loss reduction performance of Tier 3 packages

Figure 16 plots the distribution of measured airtightness performance needed to achieve Tier 3 across the 240 archetypes.

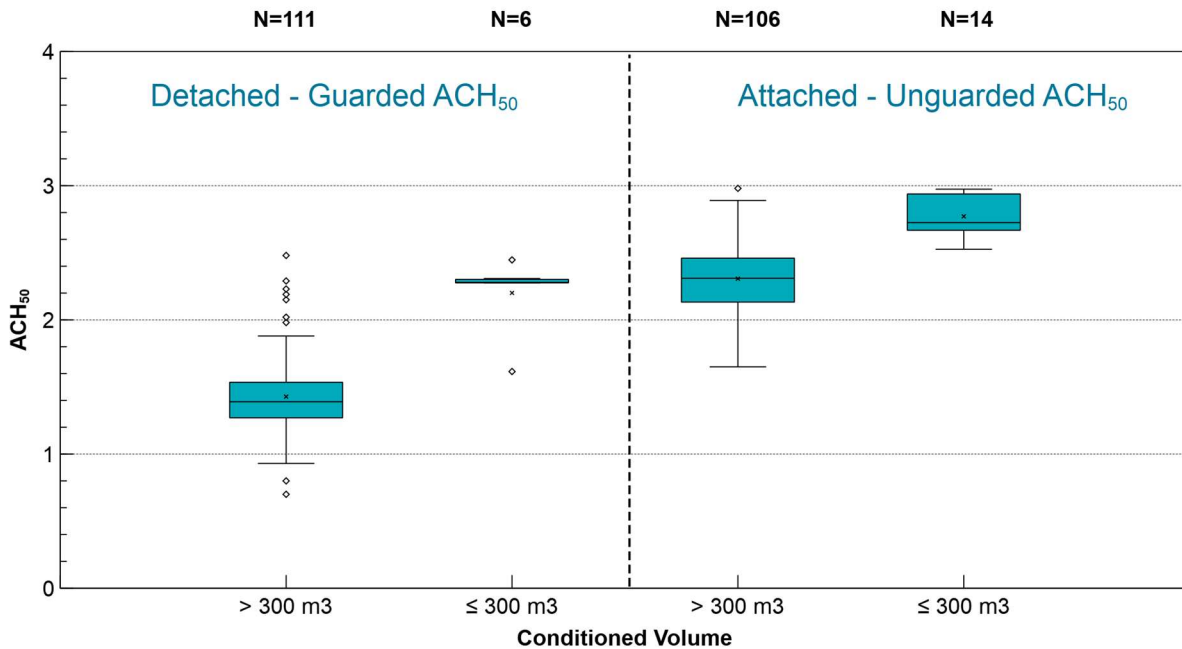


Figure 16. Distribution of archetype ACH<sub>50</sub> performance to achieve Tier 3

The two plots on the left in Figure 16 represent the 120 detached archetypes which would use 2.5 ACH<sub>50</sub> in the reference; therefore, to gain credit for airtightness they must achieve an ACH<sub>50</sub> of 2.5 or less. It can be seen in

Figure 16 that homes with conditioned volumes greater than 300 m<sup>3</sup> tended to need higher airtightness performance (average of 1.43 ACH<sub>50</sub>) compared to the smaller homes (average 2.20 ACH<sub>50</sub>) since the energy requirements are more stringent for larger homes under the Tiered energy performance path. The two plots on the right in Figure 16 represent distribution of the unguarded ACH<sub>50</sub> performance needed by the 120 attached archetypes to meet Tier 3. Here, the reference building is modelled with 3.0 ACH<sub>50</sub> since the proposed model is simulated with measured unguarded performance. It can be seen in Figure 16 that homes with a conditioned volume greater than 300 m<sup>3</sup> required higher airtightness performance (average 2.31 ACH<sub>50</sub>) to meet Tier 3 compared to the smaller homes (average 2.77 ACH<sub>50</sub>).

### 4.3.1 Impact of PCF 1819 on 2020 NBC Compliant Solutions

Once all the Tier 3 compliance packages were determined for each archetype under 2020 NBC requirements, their solutions were fixed and their compliance was re-evaluated under the provisions of PCF 1819. The reference models for all the archetypes were updated per PCF 1819, and for the attached homes the proposed models were updated by using Equation (11) to determine proposed model airtightness performance input ( $ACH_{50,model}$ ) from the unguarded performance ( $ACH_{50,measured,UG}$ ). For detached homes using airtightness testing for compliance under the Tiered energy performance path PCF 1819 does not alter the proposed model.

Figure 17 plots the distributions of the absolute difference in calculated percent improvement when PCF 1819 is used to evaluate the Tier 3 packages compared to 2020 NBC. A negative value indicates that a lower percent improvement is achieved under PCF 1819. Per Figure 15, those archetypes precisely meet the 20% Tier 3 percent improvement requirement, and therefore, a drop in calculated percent improvement would put them out of compliance with Tier 3.

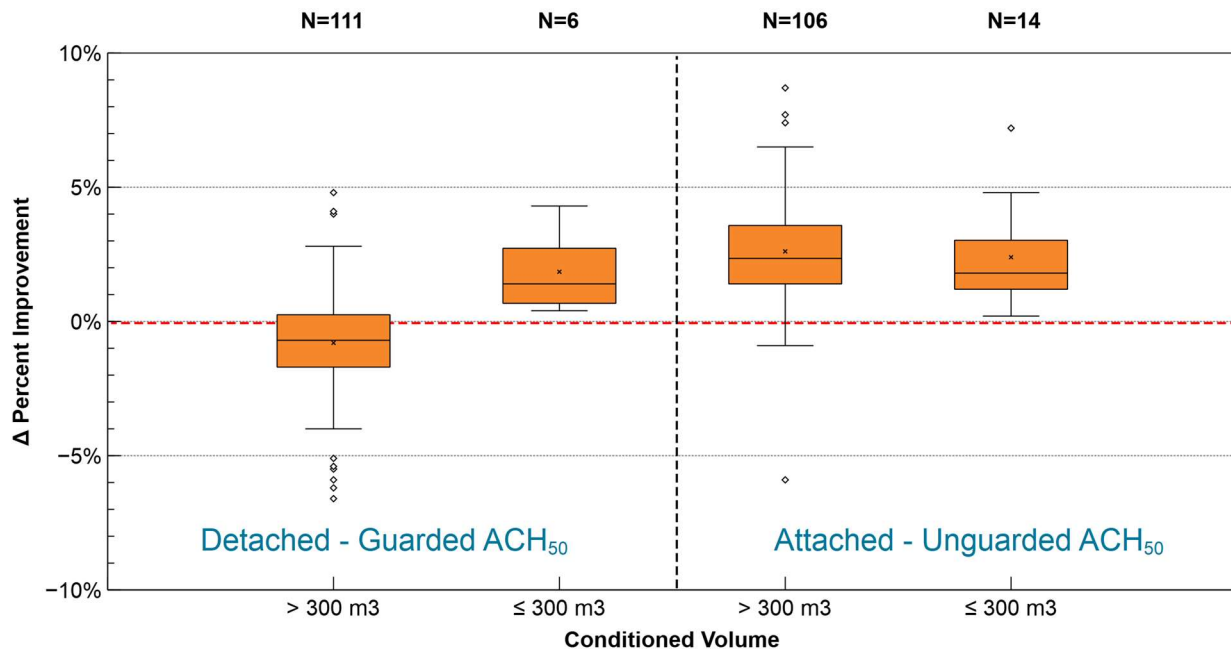


Figure 17. Change in calculated percent improvement

Figure 18 plots the change in the calculated percent heat loss reduction if PCF 1819 is adopted. The trends are similar to those in Figure 17; the detached homes with conditioned volumes greater than 300 m<sup>3</sup> will achieve a reduced percent heat loss reduction under PCF 1819 compared to 2020 NBC requirements. Per Figure 15, the Tier 3 packages for these homes tended to over-perform in terms of the percent heat loss reduction requirement;

however, coupled with the drop in percent improvement they would still fall out of Tier 3 compliance under PCF 1819.

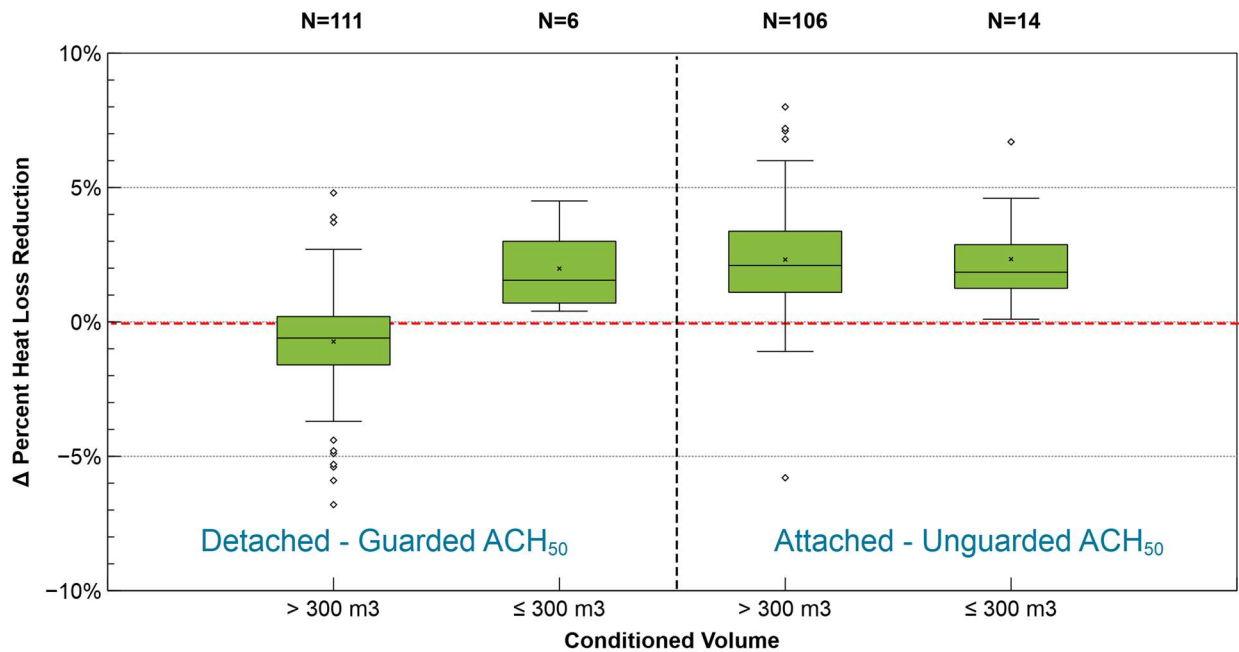


Figure 18. Change in calculated percent heat loss reduction

All other archetypes (smaller detached, and all attached archetypes) tend to benefit from PCF 1819 in terms of awarding more energy savings for the same design. This would allow for a reduction in energy performance of those archetypes while still maintaining compliance; i.e., they could meet Tier 3 with a lower airtightness performance, or trade-off elsewhere by maintaining the same airtightness performance and reducing the performance of other envelope components or equipment. Of the 237 new construction archetypes for which Tier 3 packages were developed, 154 (or 65%) receive a relaxation for performance compliance under PCF 1819; that is, lower envelope, and/or equipment performance may be utilized in 65% of the evaluated archetypes under PCF 1819 while still maintaining compliance compared with Tier 3. Conversely, 35% of the archetypes would fall out of compliance and require additional energy conservation measures under PCF 1819.

### 4.3.2 Comparison of PCF 1819 and 2020 NBC Tier 3 Annual Performance

To further explore the impact of PCF 1819, a second Tier 3 solution set was generated using the search method described previously in Section 3.4 of this report. For this solution set, however, the proposed provisions in PCF 1819 were used to define Tier 3 compliance. Figure 19 plots the distributions of measured ACH<sub>50</sub> needed to precisely meet Tier 3 (in addition to the energy conservation measures in Table 3) under both NBC 2020 and PCF 1819 requirements. It can be seen in Figure 19 that generally larger detached buildings are required to achieve a higher airtightness performance under PCF 1819 compared to NBC 2020 to maintain their Tier 3 compliance, whereas smaller-detached and attached homes receive a relaxation and can meet Tier 3 with a lower airtightness performance. This follows the trends shown previously in Figures 17 and 18.

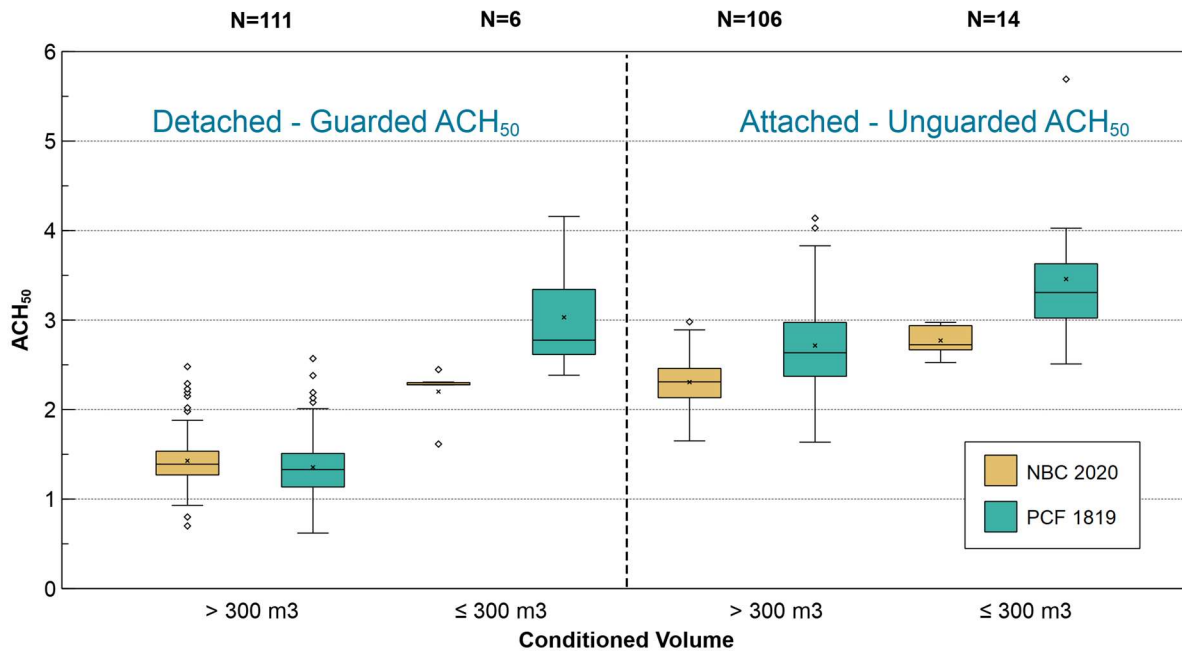


Figure 19. Change in archetype airtightness performance requirements for Tier 3 compliance under NBC 2020 and PCF 1819

The principal statistics of the data plotted in Figure 19 are provided in Table 40.

Table 40. Summary statistics of measured ACH<sub>50</sub> performance required for Tier 3 solution sets

Attachment Type	Conditioned Volume [m <sup>3</sup> ]	Average ACH <sub>50</sub>		Maximum ACH <sub>50</sub>		Minimum ACH <sub>50</sub>	
		NBC 2020	PCF 1819	NBC 2020	PCF 1819	NBC 2020	PCF 1819
Detached (guarded)	> 300	1.43	1.36	2.48	2.57	0.70	0.62
	≤ 300	2.20	3.03	2.45	4.16	1.62	2.38
Attached (unguarded)	> 300	2.31	2.72	2.98	4.14	1.65	1.64
	≤ 300	2.77	3.46	2.97	5.69	2.53	2.51

For each archetype the difference in measured ACH<sub>50</sub> (guarded for detached, unguarded for attached) required to meet Tier 3 was calculated between the package developed under NBC 2020 compliance and the package developed under PCF 1819 compliance ( $\Delta$ ACH<sub>50</sub>); a negative value indicates the archetype needs to achieve a higher performance (i.e., lower ACH<sub>50</sub>) under PCF 1819 compared to NBC 2020 requirements. The distributions of  $\Delta$ ACH<sub>50</sub> calculated for each archetype are plotted in Figure 20.

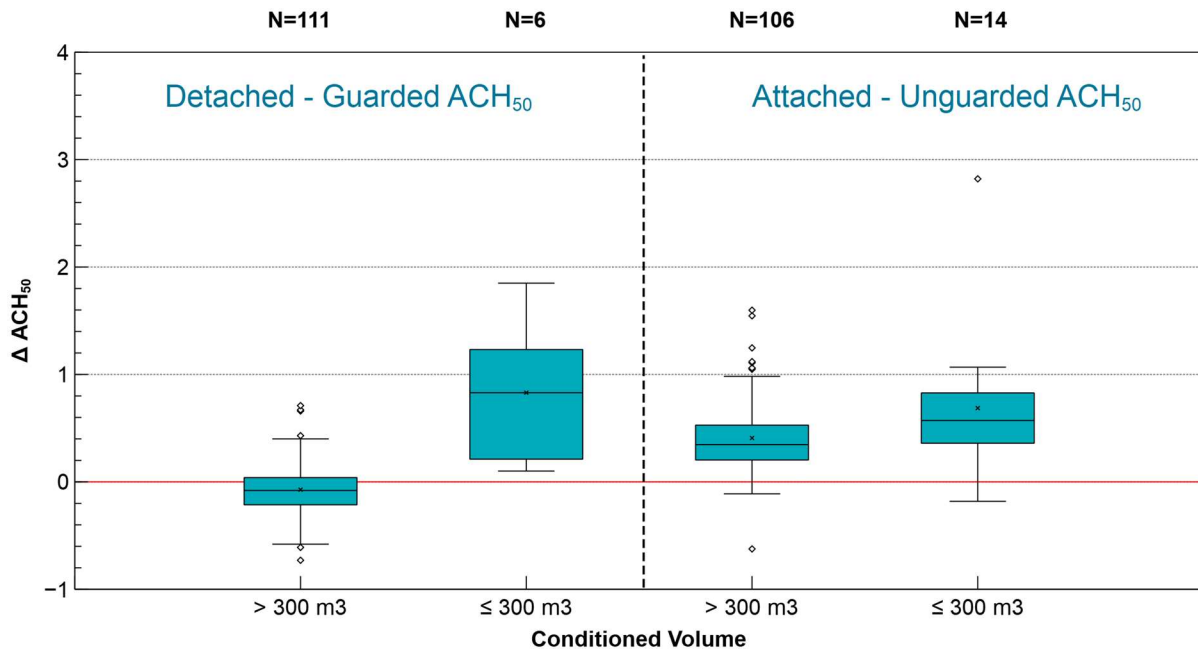


Figure 20. Distributions of changes in ACH<sub>50</sub> performance required for Tier 3 compliance

As expected, the trends in Figure 20 are similar to those in Figures 17 and 18; the larger detached homes generally have negative  $\Delta ACH_{50}$ , meaning they will need to achieve higher airtightness performance to maintain Tier 3 compliance. On average, the larger detached archetypes need to reduce their ACH<sub>50</sub> by 0.07 to maintain compliance with Tier 3 under PCF 1819, with a maximum reduction of 0.73 ACH<sub>50</sub>. The small detached archetypes, which are represented by only 6 archetypes, on average can have 0.74 ACH<sub>50</sub> *higher* measured airtightness and still comply, with the maximum relaxation of an additional 1.24 ACH<sub>50</sub> compared to what is needed under NBC 2020. For the attached larger and smaller archetypes, the average increases in ACH<sub>50</sub> permitted under PCF 1819 while still maintaining Tier 3 compliance are 0.41 and 0.69 ACH<sub>50</sub>, respectively. The principal statistics of the data plotted in Figure 20 are provided in Table 41.

Table 41. Summary statistics of measured  $\Delta ACH_{50}$  for Tier 3 solution sets

Attachment Type	Conditioned Volume [m <sup>3</sup> ]	Number of Archetypes	Average $\Delta ACH_{50}$	Maximum $\Delta ACH_{50}$	Minimum $\Delta ACH_{50}$
Detached (guarded)	> 300	111	-0.07	0.71	-0.73
	$\leq 300$	6	0.83	1.85	0.10
Attached (unguarded)	> 300	106	0.41	1.60	-0.62
	$\leq 300$	14	0.69	2.82	-0.18

It can be seen that the largest changes in ACH<sub>50</sub> required for compliance are for archetypes with conditioned volumes  $\leq 300$  m<sup>3</sup>; with a small detached archetype seeing the required ACH<sub>50</sub> for Tier 3 reducing by 1.85 ACH<sub>50</sub> under PCF 1819 compared to 2020 NBC, and a small archetype seeing the required ACH<sub>50</sub> for Tier 3 reducing by 2.82 ACH<sub>50</sub> under PCF 1819 compared to 2020 NBC.

To analyze the operational impacts of PCF 1819, annual total building site energy (utility) consumption estimates for the two solution sets (2020 NBC and PCF 1819 Tier 3 compliant) were generated using the HOT2000 proposed building models. For the PCF 1819 Tier 3 solution set, the proposed model performance calculations were used directly since the modelled airtightness performance is assumed to be the “guarded” performance, and therefore, a better representation of infiltration experienced during operation. For the 2020 Tier 3 solution set, the proposed models of the attached archetypes were re-simulated with an estimation of their “guarded” airtightness performance using Equation (11). This was done in order avoid overestimation of infiltration during building operation.

Figure 21 plots the percent savings of annual utility energy use of the PCF 1819 solution relative to the 2020 NBC solutions.

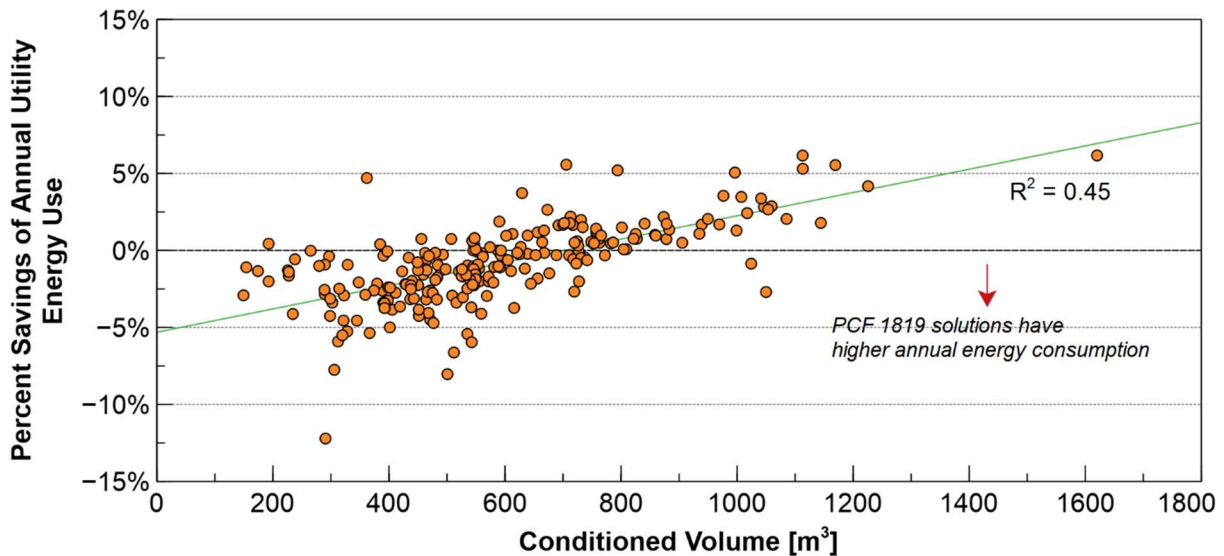


Figure 21. Percent savings of PCF 1819 Tier 3 solutions compared to 2020 NBC

There is significant scatter ( $R^2=0.45$ ), but the general trend is archetypes with smaller conditioned volumes experience an *increase* in annual utility energy consumption under PCF 1819 compared to 2020 NBC. Across all 237 archetypes for which Tier 3 solutions were found, 155, or 65.4%, yield higher annual utility energy consumption under PCF 1819 than 2020 NBC.

Space conditioning is the most directly impacted end-use of the buildings in this case study, since airtightness performance is the only design parameter that varies between the 2020 NBC and PCF 1819 solutions. Figure 22 plots the absolute and percent savings of annual space heating load achieved by the PCF 1819 solutions compared to the 2020 NBC solutions.

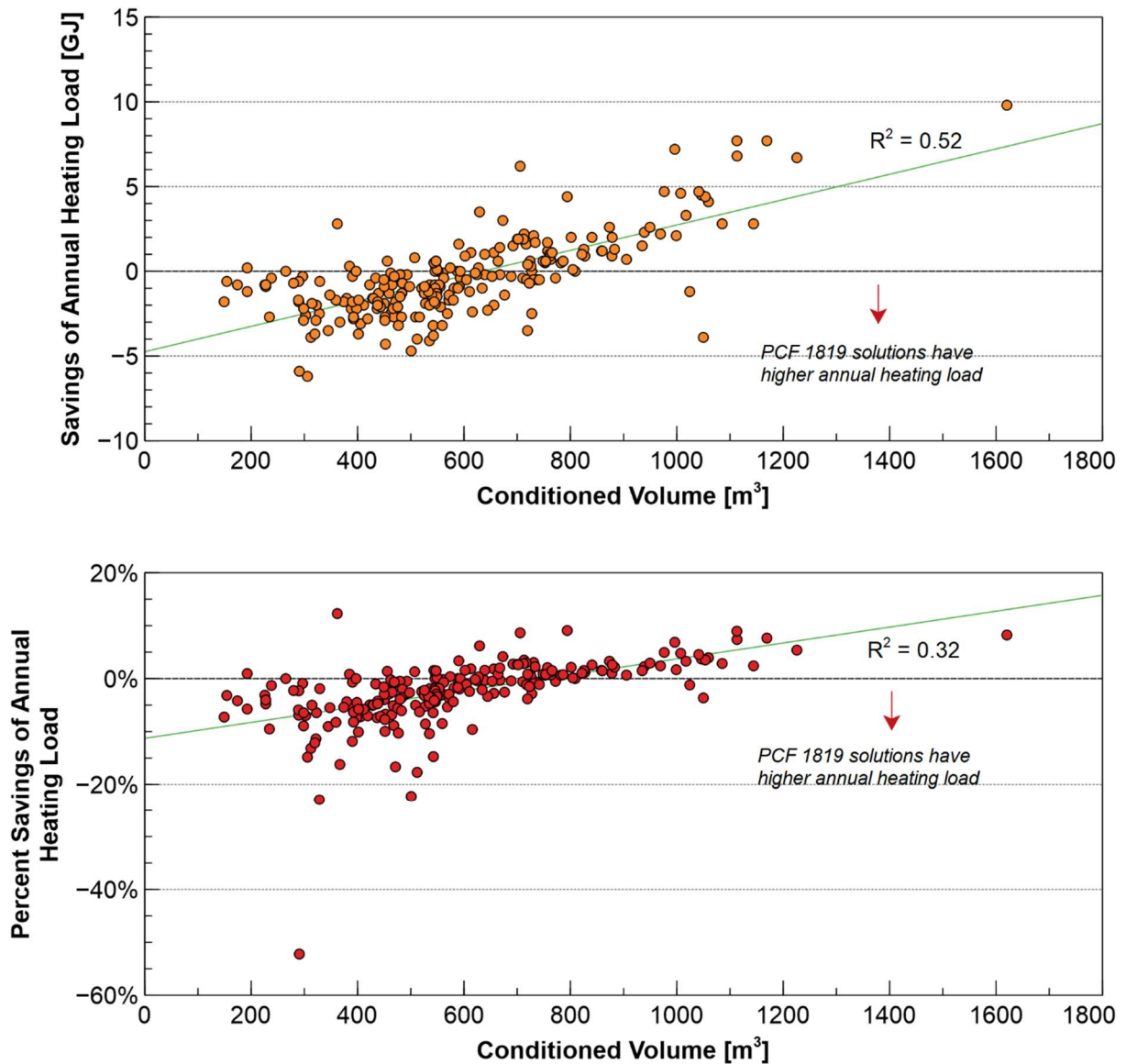


Figure 22. Absolute and percent savings of annual heating load of PCF 1819 Tier 3 solutions compared to 2020 NBC

Of the 237 archetypes for which Tier 3 solutions were found, 151, or 63.7%, have higher annual heating load under PCF 1819 compared to NBC 2020. The maximum *increase* if PCF 1819 is adopted is 6.2 GJ/year, and the maximum *savings* is 9.8 GJ/year. The unweighted average is 0.4 GJ/year *increase* in annual heating load, with a standard deviation of 2.3 GJ/year. Although there is weak correlation ( $R^2$  values of 0.52 and 0.32), the general trend is homes with smaller conditioned volumes will see an increase in annual heating load under PCF 1819 compared to 2020 NBC. Conversely, larger homes (approximately greater than 600 m<sup>3</sup>) will typically achieve savings in annual heating load under PCF 1819 compared to 2020 NBC. The distribution of annual heating load savings is plotted in Figure 23.

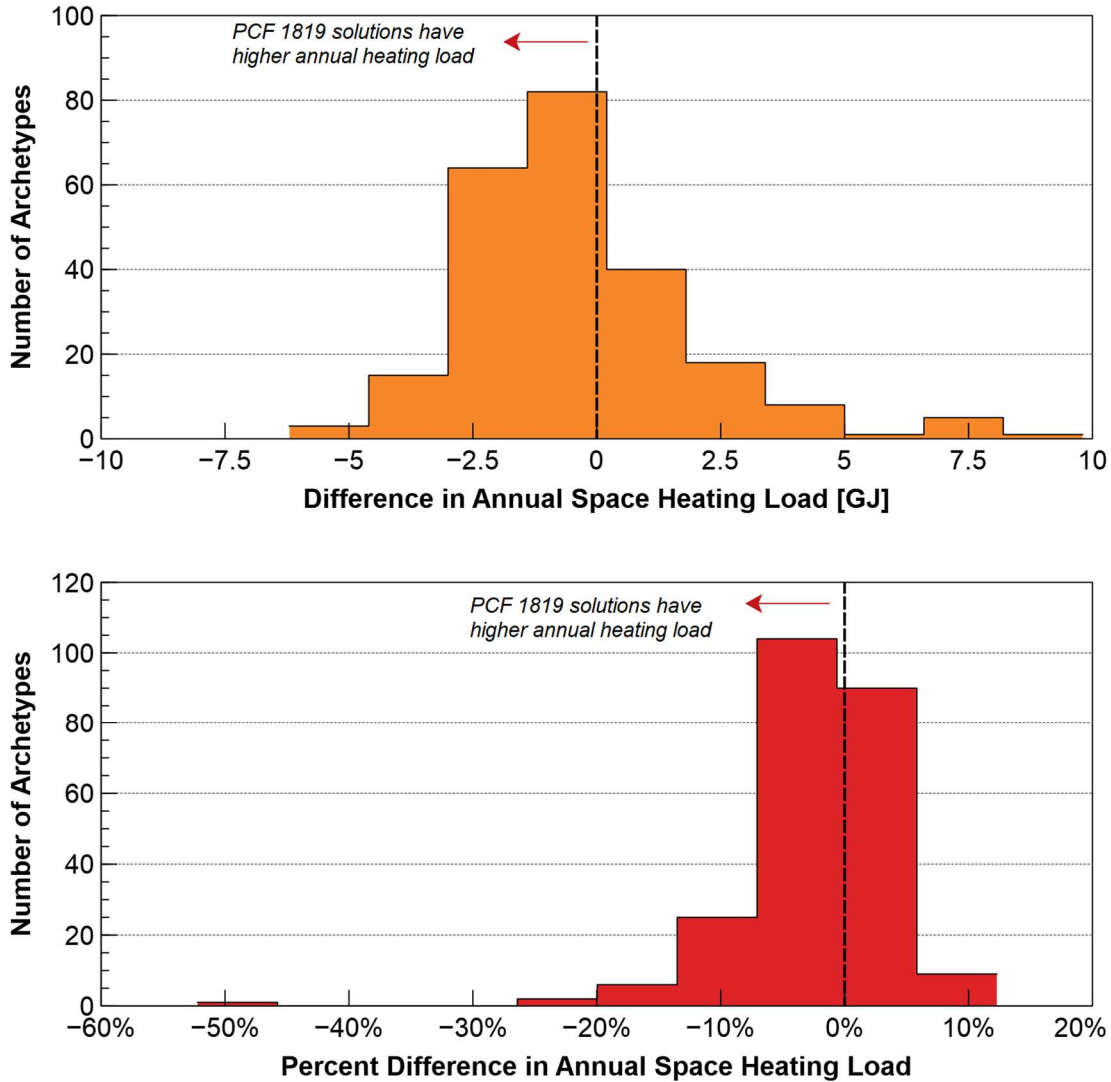


Figure 23. Distribution of difference in annual space heating loads for Tier 3 solutions

The absolute impact in operational costs for this case study are influenced by both space heating equipment efficiency, and cost of the heating fuel. Both of these parameters tend to vary geographically. For example, Climate 7A locations in Québec will likely use electricity for space heating with a thermal efficiency of 100%. A 2.0 GJ/year *increase* in space heating load<sup>3</sup> and an electricity energy price of \$30.44/GJ (CER, 2024) yields an additional \$60.88/year in space heating costs. Most residential space heating systems in New Brunswick are electric (NRCan, 2023), and with an estimated electricity cost of \$53.72/GJ (CER, 2024), a 2.0 GJ/year increase of space heating load in Climate Zone 7A locations (e.g., Edmundston, Bathurst, Grand Falls) is \$107.44/year. Warmer climates would yield smaller absolute differences in heating load between PCF 1819 and 2020 NBC, and colder climates would yield larger differences. Similarly, higher Tiers would yield larger absolute differences compared to lower Tiers.

<sup>3</sup> 55 of the 237 archetypes have an annual *increase* in space heating load equal to or greater than 2.0 GJ.

## 5 Discussion

PCF 1819 changes the way in which compliance is calculated across all pathways in Section 9.36 of the NBC. The magnitude and direction (relaxed or more stringent) of the PCF's impact relative to current code varies by several factors, including pathway taken for compliance, whether airtightness testing is conducted or not, construction of the air barrier, and whether the building is attached or not. This report explored how PCF 1819 impacts those various compliance pathways and scenarios.

### 5.1 Performance Path

Under the performance path, a builder may or may not elect to use airtightness as an energy conservation measure for compliance. Tables 42 and 43 summarize how different pathways through the base performance path of Subsection 9.36.5. and Tiered energy performance path of 9.36.7. are affected, respectively, by PCF 1819.

Table 42. Summary of impacts to the performance path in Subsection 9.36.5.

Attachment	Was Airtightness Test Done?	Was Air Barrier Constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10.	Impact of PCF 1819 relative to 2020 NBC
Detached	No	No	<ul style="list-style-type: none"> <li>• <b>Most buildings will need to implement additional energy conservation measures to comply</b></li> </ul>
		Yes	<ul style="list-style-type: none"> <li>• <b>Minimal impact</b> <ul style="list-style-type: none"> <li>○ <math>A_e/V &gt; 0.780 \text{ m}^2/\text{m}^3</math>: some relaxation/more credit given</li> <li>○ <math>A_e/V &lt; 0.780 \text{ m}^2/\text{m}^3</math>: may require additional measures to comply</li> <li>○ <math>A_e/V = 0.780 \text{ m}^2/\text{m}^3</math>: no impact</li> </ul> </li> </ul>
	Yes	Not applicable	<ul style="list-style-type: none"> <li>• <math>A_e/V &gt; 0.780 \text{ m}^2/\text{m}^3</math>: relaxation/more credit given. Can comply with lower airtightness performance</li> <li>• <math>A_e/V &lt; 0.780 \text{ m}^2/\text{m}^3</math>: require additional measures to comply. Need higher airtightness performance to comply</li> <li>• <math>A_e/V = 0.780 \text{ m}^2/\text{m}^3</math>: no impact</li> <li>• 40% of detached archetypes obtain relaxation</li> <li>• 60% of detached archetypes have higher requirements</li> </ul>
Attached	No	No	<ul style="list-style-type: none"> <li>• <b>Most buildings will receive relaxation</b>, fewer measures need to be implemented to comply</li> </ul>
		Yes	<ul style="list-style-type: none"> <li>• <b>Minimal impact</b> <ul style="list-style-type: none"> <li>○ <math>A_e/V &gt; 0.593 \text{ m}^2/\text{m}^3</math>: some relaxation/more credit given</li> <li>• <math>A_e/V &lt; 0.593 \text{ m}^2/\text{m}^3</math>: may require additional measures to comply</li> </ul> </li> </ul>
	Yes/Guarded	Not applicable	<ul style="list-style-type: none"> <li>• <math>A_e/V &gt; 0.593 \text{ m}^2/\text{m}^3</math>: relaxation/more credit given. Can comply with lower airtightness performance</li> <li>• <math>A_e/V &lt; 0.593 \text{ m}^2/\text{m}^3</math>: require additional measures to comply. Need higher airtightness performance to comply</li> <li>• <math>A_e/V = 0.593 \text{ m}^2/\text{m}^3</math>: no impact</li> <li>• 82.5% of attached archetypes obtain relaxation</li> </ul>
	Yes/Unguarded		<ul style="list-style-type: none"> <li>• <math>A_T/V &gt; 0.712 \text{ m}^2/\text{m}^3</math>: able to obtain credit at lower unguarded airtightness performance</li> <li>• <math>A_T/V &lt; 0.712 \text{ m}^2/\text{m}^3</math>: need to achieve higher unguarded airtightness performance to obtain credit</li> <li>• <math>A_T/V = 0.712 \text{ m}^2/\text{m}^3</math>: minimal impact</li> <li>• 96.7% of attached archetypes obtain relaxation</li> </ul>

Table 43. Summary of impacts to the performance path in Subsection 9.36.7.

Attachment	Was Airtightness Test Done?	Was Air Barrier Constructed to Subsection 9.25.3. and Articles 9.36.2.9. and 9.36.2.10.	Impact of PCF 1819 relative to 2020 NBC
Detached	No	No	<ul style="list-style-type: none"> <li>• <b>Most buildings will need to implement additional energy conservation measures to comply</b></li> </ul>
		Yes	<ul style="list-style-type: none"> <li>• <b>Most buildings will receive relaxation</b>, fewer measures need to be implemented to comply</li> </ul>
	Yes	N/A	<ul style="list-style-type: none"> <li>• <math>A_e/V &gt; 0.780 \text{ m}^2/\text{m}^3</math>: relaxation/more credit given. Can comply with lower airtightness performance</li> <li>• <math>A_e/V &lt; 0.780 \text{ m}^2/\text{m}^3</math>: require additional measures to comply. Need higher airtightness performance to comply</li> <li>• <math>A_e/V = 0.780 \text{ m}^2/\text{m}^3</math>: no impact</li> <li>• 40% of detached archetypes obtain relaxation</li> <li>• 60% of detached archetypes have higher requirements</li> </ul>
Attached	No	No	<ul style="list-style-type: none"> <li>• <b>Most buildings will receive relaxation</b>, fewer measures need to be implemented to comply</li> </ul>
		Yes	<ul style="list-style-type: none"> <li>• <b>Most buildings will receive relaxation</b>, fewer measures need to be implemented to comply</li> </ul>
	Yes/Guarded	N/A	<ul style="list-style-type: none"> <li>• <math>A_e/V &gt; 0.593 \text{ m}^2/\text{m}^3</math>: relaxation/more credit given. Can comply with lower airtightness performance</li> <li>• <math>A_e/V &lt; 0.593 \text{ m}^2/\text{m}^3</math>: require additional measures to comply. Need higher airtightness performance to comply</li> <li>• <math>A_e/V = 0.593 \text{ m}^2/\text{m}^3</math>: no impact</li> <li>• 82.5% of attached archetypes obtain relaxation</li> </ul>
	Yes/Unguarded		<ul style="list-style-type: none"> <li>• <math>A_T/V &gt; 0.712 \text{ m}^2/\text{m}^3</math>: able to obtain credit at lower unguarded airtightness performance</li> <li>• <math>A_T/V &lt; 0.712 \text{ m}^2/\text{m}^3</math>: need to achieve higher unguarded airtightness performance to obtain credit</li> <li>• <math>A_T/V = 0.712 \text{ m}^2/\text{m}^3</math>: minimal impact</li> <li>• 96.7% of attached archetypes obtain relaxation</li> </ul>

### 5.1.1 Airtightness Testing Not Performed

The largest impact of PCF 1819 is from alignment of proposed building modelling rules for airtightness in Subsection 9.36.7. with Subsection 9.36.5.: allowing the proposed building to use the same airtightness performance as the reference, if the air barrier is constructed to the extra prescriptive measures. Sections 4.1.1.1.3 and 4.1.2.1.3 showed that the “calculated” percent savings of above-grade wall energy conservation measures more than double under the proposed changes in PCF 1819. This change may be interpreted as a relaxation in requirements compared to 2020 NBC; i.e., less energy conservation measures are needed under PCF 1819 to achieve the same Tier as would be required under 2020 NBC, if no airtightness test is performed and the air barrier is not constructed to the extra requirements.

For Subsection 9.36.5., if PCF 1819 is adopted there is minimal impact for the scenario where no airtightness testing is done and the air barrier is constructed to the extra prescriptive measures. Under this scenario, in both the 2020 NBC and PCF 1819, both the reference and proposed models use the same airtightness performance. Therefore, there is no performance gap in airtightness performance between the reference and proposed buildings, and the savings calculated from other energy conservation measures are largely unaffected. Subsections 4.1.1.1.1 and 4.1.2.1.1 show, however, that there is *some* variation in the percent improvement calculations when PCF 1819 is applied. This is due to PCF 1819 altering the proportional contribution of infiltration to annual energy performance. For the energy conservation measures, climates, and archetypes examined in this report, PCF 1819 altered the calculated percent improvement by less than a percentage point.

For the scenarios when no airtightness testing is done, and the air barrier is not constructed to the extra prescriptive measures, the following impacts of PCF 1819 were found for both Subsections 9.36.5. and 9.36.7.:

- Most detached homes will need to implement additional energy conservation measures to maintain compliance,
- Most attached homes will receive a relaxation compared to 2020 NBC.

### 5.1.2 Airtightness Testing Performed

When airtightness testing is used for performance path compliance, 82.5% and 96.7% of the 120 attached new construction archetypes receive a relaxation when guarded and unguarded testing is performed, respectively. For the detached archetypes, 40% receive a relaxation. Whether PCF 1819 provides an increase or relaxation in requirements is dictated by the building's  $A/V$  ratio:

- Detached homes with an  $A_e/V$  ratio above  $0.780 \text{ m}^2/\text{m}^3$  receive a relaxation, and those below have higher requirements;
- Attached homes with  $A_e/V$  ratio above  $0.593 \text{ m}^2/\text{m}^3$  receive a relaxation for *guarded* testing, and those below have higher requirements;
- Attached homes with  $A_T/V$  ratio above  $0.712 \text{ m}^2/\text{m}^3$  receive a relaxation for *unguarded* testing, and those below have higher requirements.

PCF 1819 affects the performance path compliance calculation in this scenario in two ways. First, the minimum airtightness performance needed to begin obtaining credit changes under PCF 1819. Under 2020 NBC, detached buildings need to achieve a performance greater than 2.5 ACH<sub>50</sub> to begin obtaining credit in the performance path. Below this performance (i.e., greater than 2.5 ACH<sub>50</sub>), no credit *or penalty* is assigned, and the proposed model would use a codified value of 2.5 ACH<sub>50</sub> performance. PCF 1819 alters this minimum threshold. This was shown previously in Figure 11 for detached archetypes ERS-1073 and ERS-1048. Under PCF 1819 their reference airtightness performance changes to 1.94 and 3.43 ACH<sub>50</sub>, respectively. ERS-1048 can start obtaining credit for airtightness performance once a performance below 3.43 ACH<sub>50</sub> is achieved. ERS-1073 must have a performance better than 1.94 ACH<sub>50</sub> to obtain credit.

The second way in which PCF 1819 affects the performance path compliance calculation in this scenario is that it alters the amount of credit that is provided for a given airtightness performance. For example, using Figure 14, if attached archetype ERS-3060 achieved an unguarded airtightness of 2.0 ACH<sub>50</sub> in Climate Zone 7A, the corresponding percent improvement allocated for that measure is 7.2%. Under PCF 1819, the same unguarded airtightness performance (2.0 ACH<sub>50</sub>) yields a corresponding percent improvement of 10.3%. If the design solution was compliant under 2020 NBC, the additional credit *could be* used to reduce airtightness performance, envelope, and/or mechanical systems performance while still maintaining compliance.

### 5.1.3 Tier 3 Case Study

As higher Tiers are adopted as the minimum for compliance in Section 9.36, builders will likely have to update or develop new solutions to maintain compliance with the code. The objective of the Tier 3 case study in this report was to analyze the impact to operational performance of those “future” solutions if PCF 1819 is adopted instead of maintaining the status quo. Two Tier 3 solutions for Climate Zone 7A were developed for each of the 237<sup>4</sup> new construction archetypes: one compliant with 2020 NBC, and one compliant with PCF 1819. Each solution was “strictly” compliant with Tier 3 as defined in the Tiered Performance Path; that is, any reduction in performance of the envelope would result in the solution no longer complying. All solutions used airtightness testing as part of their designs, and attached buildings were assumed to use “unguarded” airtightness testing.

The impact to compliance of the 2020 NBC solutions *if* PCF 1819 were adopted was first investigated. It was found that 35%, or 83 of the 237, archetypes would fall out of compliance if PCF 1819 were to be adopted. The purpose of this analysis was to evaluate the impact to contemporary users of the Tiered Energy Performance Compliance Path. While Tier 3 and Climate Zone 7A was used to facilitate the impact calculations, these observations may be extended to other Tiers, the base performance path in Subsection 9.36.5., and other Climate Zones, as long as airtightness testing is being used as a measure of compliance. This is because it is the geometry, specifically the  $A/V$  ratio of the building, that determines how PCF 1819 affects compliance, not the Tier or climate. What the initial analysis in this case study shows is that generally detached buildings using the performance path and airtightness testing for compliance will receive less credit under PCF 1819, and may consequently fall out of compliance and need to implement additional measures. The other 65% of the archetypes, generally attached and small detached, receive additional credit under PCF 1819 and would not need to alter their designs for compliance. They could, however, optionally reduce the performance of their designs to reduce costs while maintaining compliance.

The second part of the case study estimated the operational impacts of PCF 1819 compared to 2020 NBC. Again, Tier 3 and Climate Zone 7A was used to provide absolute values, but the general observations can be extended to other Tiers and Climate Zones (provided both the performance path and airtightness testing is being done). The relaxations and increases requirements resulting from the adoption of PCF 1819 translate to increases and decreases in annual operational energy, respectively. Figure 21 showed some ( $R^2=0.45$ ) positive correlation between conditioned volume and percent savings of annual utilities if PCF 1819 is adopted; i.e., as buildings get larger, the percent *savings* in annual utility energy use increases. The graph also shows that around a conditioned volume of 700 m<sup>3</sup> the savings change from positive to negative (i.e., more annual utility energy use if PCF 1819 is adopted).

## 5.2 Prescriptive Path

The 2020 NBC introduced Subsection 9.36.6. which describes the airtightness testing procedure for Section 9.36 compliance, as well as introduced the airtightness “levels”. Two sets of airtightness levels are currently provided in the code. Table 9.36.6.4.-A defines airtightness levels AL-1A to AL-5A which apply to testing of detached buildings and guarded testing of attached buildings. Table 9.36.6.4.-B defines airtightness levels AL-1B to AL-6B which applies to unguarded testing of attached buildings. Each level is defined using three separate metrics:  $ACH_{50}$ ,  $NLR_{50}$ , and  $NLA_{10}$ . In the 2020 NBC, these levels are only utilized for determining energy conservation points allocated for airtightness testing under the Tiered Prescriptive Path in Subsection 9.36.8.

PCF 1819 proposes to remove  $ACH_{50}$  from the definitions of the airtightness levels, maintaining only the area-normalized metrics  $NLR_{50}$  and  $NLA_{10}$ . The impact of the proposed change is that buildings relying on  $ACH_{50}$

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<sup>4</sup> Tier 3 solutions were not found for 3 detached archetypes.

performance to obtain credits under the performance path will need to increase their airtightness performance to maintain compliance. The results showed that between 60 and 67% of the 120 detached archetypes would need to increase their airtightness performance to maintain their airtightness level. If guarded test is done, 79 to 81% of the 120 attached archetypes would need to increase their performance to maintain their level. For unguarded testing, 3 to 4% of the 120 attached archetypes would need to increase their airtightness performance to maintain compliance. PCF 1819 does not impart any relaxations in the prescriptive path.

## 6 Conclusions

This report analyzed impacts from adopting PCF 1819 relative to current requirements in the 2020 NBC. The assessment used 240 new construction archetypes developed by Asaee & Ferguson (2019) to quantify how building energy efficiency and performance will be affected in all prescriptive and performance compliance paths in Section 9.36. The analysis demonstrates that PCF 1819 has a varying impact based on several factors including compliance path being used, building attachment, whether an airtightness test is done for compliance or not, and geometry of the building. Fourteen scenarios under the performance compliance paths (base and Tiered) were identified and analyzed: six for detached buildings, and eight for attached.

The impact assessment showed that for cases where airtightness is not used as a measure for compliance, PCF 1819 has limited impact. The exception to this is in the Tiered Performance Path, where PCF 1819 proposes to allow modelling the proposed reference house with the same airtightness performance as the reference. This provides a relaxation since 2020 code requires the proposed model to assume lower airtightness performance if airtightness testing is not done. For scenarios in the performance path where airtightness is used as a measure for compliance, the study showed that the impact of PCF 1819 is dictated by the surface-to-volume ratio of the proposed building. Based upon the 240 new construction archetypes, larger detached homes will need to achieve higher airtightness performance and/or incorporate additional energy conservation measures to achieve compliance, and attached and smaller homes may use reduced airtightness performance and/or relax other energy conservation measures when seeking compliance in the performance path.

The proposed changes to the prescriptive path brought forth by PCF 1819 only increase requirements, primarily for larger detached homes, or has no impact. The larger detached home archetypes considered in this study tended to have surface-to-volume ratios that favoured using  $ACH_{50}$  rather than  $NLR_{50}$  for determining airtightness level. By removing  $ACH_{50}$  in the airtightness level and obligating the use of the area-normalized metrics  $NLR_{50}$  or  $NLA_{10}$ , those archetypes would need to achieve a tighter air barrier to maintain their targeted airtightness level. Since the attached and smaller archetypes tended to have surface-to-volume ratios that favoured using  $NLR_{50}$  to define their airtightness level, therefore, PCF 1819 has no impact on those archetypes.

The case study was used in this analysis to evaluate the potential impact of operational performance of new construction as higher tiers are adopted as the minimum requirement. The study showed that if PCF 1819 is adopted, smaller homes complying using the performance path, and airtightness testing, may be less energy efficient and have higher operational costs compared to not adopting the changes. Fewer energy conservation measures, however, would likely correspond to some reductions in capital costs for construction.

An important impact to consider for PCF 1819 is the consistency of compliance determination and outcomes. Per the Long-Term Strategy policy paper from CCBFC (2016), the intention of the Tiered codes was to set a pathway for industry to signal where the regulation is going. The 2015 NBC was used, with some alterations, as the baseline upon which the tiers were defined, with each tier being defined as “percent better than” the baseline. The impact analysis has shown that PCF 1819 alters this baseline, and subsequently what is and is not compliant. The general observation is that any current user of the performance path, and airtightness testing, for compliance will need to re-evaluate their design solutions should PCF 1819 be adopted. Based on the archetypes considered in this study, larger detached homes using this compliance path may fall out of compliance and have would have to refine their designs.

## 7 Future Work

If PCF 1819 is to proceed, there needs to be additional analysis to assess its impacts and interactions with other sections of the NBC. The energy conservation points in Subsection 9.36.8. were all determined using the 240 new construction archetypes from Asaee & Ferguson (2019), and the reference versus proposed performance calculation in Subsection 9.36.5. (Wills, Macdonald, & Knudsen, 2022). That calculation procedure was adopted to maintain some alignment and similarity in compliance outcomes between the performance and prescriptive paths. Section 4.1.2.2.2 of this report showed that PCF 1819 generally increased the calculated percent savings for unguarded airtightness performance; therefore, to maintain alignment, the energy conservation points described in Table 9.36.8.8. for the airtightness levels in Table 9.36.6.4.-B would need to be re-evaluated.

PCF 1869 was also submitted in the same public review as PCF 1819. That PCF proposes the introduction of a performance compliance path which utilizes energy intensity instead of relative percent savings. The analyses to support the target intensity values (Gilani, Ferguson, & Stylianou, 2022) also used the existing modelling rules in Subsection 9.36.5. of the 2020 NBC. Given PCF 1819 alters the magnitude of the airtightness performance, and therefore, the modelled absolute energy performance of the building, the recommended intensity metrics should be re-evaluated using the proposed provisions under PCF 1819.

## Acknowledgments

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