COST/BENEFIT ANALYSIS

Item B-6, December 14, 2021 NC BCC Meeting

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NCDOI
325 N. Salisbury St., Raleigh, NC

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Conclusion of Cost/benefit analysis

As presently written, there is virtually no financial impact for a structure, as compared to the existing code language, because it does not appear to affect the Reference Design Glazing amount to be modeled in cases where footnote “h” is invoked, which is for residences with conditioned basements, R-2 and R-4 residences and townhouses.

In the present code-language path using existing code language and formulae, there are scenarios where the Reference Design glazing is reduced to such a small value, that, while mathematically possible, would be difficult to actually sell a building like it. The Proposed Design under the existing code language would have to imitate a model building that has the same walls, foundation, etc., as the Reference Design but a more realistic amount of glazing. No matter how good (low-heat transfer, or Btu/hr-ft^2-°F) glazing is, it is difficult to compare to a wall’s heat transfer, and this becomes a disincentive to use the Simulated Performance Path due to this requirement. Of course, this just applies if the permit holder is choosing to pursue the Simulated Performance Path code path; the prescriptive code still applies and would not affect glazing (fenestration) allowances.

In the proposed decision-tree path using modification to the present code, there are clarifications proposed to several variables, and a formula that sets the A_s at 15%, but two conditions are added to the footnote ‘h” requirement that still allow, or rather require, the Reference Design to go to a very small value under certain circumstances, using the same formula as the present code language.

Therefore, to reiterate, I could not find a scenario where I could create a formula that would allow me to show the costs or benefits between the existing code language and the proposed code language. This may or may not have been the proposer’s intent, but as proposed, there appears to be no mathematical difference for all practical purposes.

Proposed code language

The following text is from Item B-6 December 14, 2021 BCC Meeting:

Request by Jamieson Stapleton representing Southern Energy Management to amend 2018 NC Energy Code, Table 405.5.2(1) as follows.

Item B-6
Change Footnote **h** of Table 405.5.2 in the North Carolina Energy Conservation Code as Follows:
[h] For residences with conditioned basements, R-2 and R-4 residences and townhouses, the following formula shall be used
to determine glazing area: the revised reference design total glazing area shall be the lesser of :
(1) Proposed glazing area
(2) The revised reference design total glazing area calculated using the following formula: AF = As X FA X F where:
AF = ~~Total glazing area~~ Revised reference design total glazing area
As = Standard reference design total glazing area = 0.15 X Conditioned Floor Area
FA = (Above-grade thermal boundary gross wall area)/(above-grade boundary wall area + 0.5 x below-grade boundary wall area)
F = (Above-grade thermal boundary wall area)/(above-grade thermal boundary wall area + common wall area) or 0.56, whichever is greater
and where:
Thermal boundary wall is any wall that separates conditioned space from unconditioned space or ambient conditions. Above-grade
thermal boundary wall is any thermal boundary wall component not in contact with the soil. Below-grade boundary wall is any
thermal boundary wall in soil contact.
Common wall area is the area of walls shared with an adjoining dwelling unit.
~~L~~, AF, As and CFA are in the same units.

Analysis - Background

Identifying the math to be done to perform analysis

As presently written, the amount of glazing for the proposed design is contingent on the reference design. This is logical for there to be a fair, objective comparison. The minimal requirements set up in the Simulated Performance Alternative for the reference design are set up so a modeler cannot game the system and create a reference design building that would show high energy use and compare it to a proposed design that is not really very efficient but is still able to beat the performance of an artificially low-performing reference design. The Simulated Performance Alternate is not intended to be a lower-performing path (higher energy use) than the Prescriptive path, but only to provide more flexibility in the overall design. For instance, in terms of glazing, it is possible to have lots of glazing, properly oriented and of the correct U-factor and SHGC, to achieve zero heating costs, and the Simulated Performance Alternative is the path that can be used to demonstrate this scenario. However, lots of glazing without proper orientation and careful selection of U-factors and SHGC values can lead to a significantly higher energy use building.

In most cases, it would not be fair to select a reference house that is 100% glazing, albeit code-required U-factor, and then compare it to a proposed building that may have significantly higher U-factor walls (more heat transfer, Btu/hr-ft^2-°F) than the prescriptive code, but with less glazing (fenestration) that would allow the proposed building to be modeled and show less energy consumption over a year's time than the reference house. This is why many of the line-items for square footage and type of the reference building are designated as "as proposed" so as to not allow selection of easy-to-beat assemblies. However, the formula for residences with conditioned basements, R-2 and R-4 residences and townhouses the modeler is instructed to use, sets a lower value of glazing for the reference house than the Proposed house for certain lower-level percentages. All other building components held constant; the higher heat transfer of glazing (fenestration) will make it more difficult to show the proposed house will use less energy than the reference house. Whether this is intentional or a vestigial requirement not pertinent anymore is unknown, but it is the adopted code language.

There is only a subset of houses that are designed under Section R405.5.2, as there is added consultant costs to the project and perhaps added complicated design to the house that ends of being built. Therefore, the questions about footnotes to this method are very infrequent. Sections of the code that are not used much can be illogical or have flat-out errors for many code cycles before something happens that requires them to be addressed. By then, the reasons for the formulas may be lost to history if they are poorly documented and not self-evident.

Existing Code Language – Formula analysis

The general assumption as to what the comparison would be looks like this:

$AF = A_s \times FA \times F$

Where:
AF = Total glazing area
A_s = Standard reference design total glazing area
FA = (Above-grade thermal boundary gross wall area)/(above-grade boundary wall area + 0.5 x below-grade boundary wall area)
F = (Above-grade thermal boundary wall area)/(above-grade thermal boundary wall area + common wall area) or 0.56, whichever is greater

The values of FA and F vary dependent on the amount of below-grade walls, indicating basements or basement apartments, and above-grade common-wall areas indicating common walls with adjacent apartments.

Effect of FA on A_s

A simple analysis was run with various values to see what numerical values each of these variables will take on. The base case is the scenario where there are no below-grade walls. As shown in Table 1, the very first row in the table indicates that, if the below-grade wall area is zero, then the value FA takes on is one (1). Therefore, it would not change the A_s value.

Table 1: FA sample values

	$AF = A_s \times FA \times F$		
Examples of sample values			
Above GradeThermal Boundary Wall	Constant from formula	Below-grade boundary wall area)	**FA**
1000	0.5	0	1
1000	0.5	500	0.80
1000	0.5	750	0.73
1000	0.5	1000	0.67
1000	0.5	2000	0.50
1000	0.5	3000	0.40
1000	0.5	10000	0.17
1000	0.5	100000	0.02

Effect of F on A_s

Likewise, in the case where there are no common walls, the variable F is similar to FA in that it takes on a value of one (1). See Table 2 for sample values of F with various common wall values entered for illustration. As shown in the first row of values, when there are no common walls (zero common wall area) the variable F takes on a value of one (1). Therefore, in this case, the F variable would have no effect on the A_s variable.

Table 2: F sample values

	$AF = A_s \times FA \times F$		
Above GradeThermal Boundary Wall		Common wall area	**F**
1000		0	1.0
1000		500	0.7
1000		750	0.6
1000		800	0.56
1000		1000	0.5
1000		3000	0.3
1000		10000	0.1
1000		100000	0.0

When both the AF and F value are one (1), that would indicate a free-standing, no-basement house, and therefore
$AF = A_s \times 1 \times 1$ or
$AF = A_s$

This same procedure is followed for values of below-grade walls and common wall areas that are greater than zero, to illustrate the effect upon A_s at various values, and to illustrate the limits of the effect on A_s that AF and F have. In Table 3, the Above-grade thermal boundary walls value of a nominal 1000 square feet was inserted, and held constant, while the amount of Below-grade boundary wall area was incremented from zero to 100,000 square feet. The 0.5 value is from the formula and is a constant with no units of measure attached.

The FA value varies from one (1) or close to one (1) for very small values of below-grade boundary walls but then approaches zero (0) for very high values of below-grade boundary walls. Obviously, it is unusual to have the below-grade boundary walls be greater than the above-grade walls, but the exercise was done to see what the effect was on the numerical value the variable FA takes on at higher values. There are areas of the country that impose height restrictions in historic neighborhoods or seaside towns, so there are cases where the below-grade area is significantly greater than the above-grade portion but for our purposes we will focus on the smaller values.

The values likely to be encountered for a below-grade wall will likely be between zero and 100% of the above grade walls, or basically a story above grade and a story below grade. In apartments, that would likely be less, but for that range, we are looking at the variable FA taking on values of between zero (below-grade boundary = 0 sq. ft.) and 0.67 (below grade boundary = 1000 sq. ft). Whenever there is some amount of Below-grade walls, the value of FA will be less than one (1), and therefore will have the effect of reducing the A_s value, because it is being multiplied by a value smaller than one (1).

Bear in mind, this reduced A_s value is then what the modeler is required to use for the Reference design, as compared to their "As proposed" amount of glazing.

Table 3: FA sample values - Boundary walls greater than zero

	$AF = A_s \times FA \times F$		
Examples of sample values			
Above GradeThermal Boundary Wall	Constant from formula	Below-grade boundary wall area)	**FA**
1000	0.5	0	1
1000	0.5	500	0.80
1000	0.5	750	0.73
1000	0.5	1000	0.67
1000	0.5	2000	0.50
1000	0.5	3000	0.40
1000	0.5	10000	0.17
1000	0.5	100000	0.02

Next, we will look at values the F variable can reasonably take on, and the effect on A_s. In Table 4, the Above Grade thermal Boundary Wall area is held constant at 1000 sq. ft., while the Common wall area is varied between zero (0) and 100,000 sq. ft., and the reader can see the effect these values have on the value that the variable F takes on. The common wall area cannot for any conceivable reason take on a value greater than the Above Grade Thermal Boundary Wall, as that would indicate an apartment with no exterior walls, which is highly unlikely, but for illustrative reasons that would have provided a value for F of 0.5. However, the formula has a lower-limit value of 0.56, illustrated in red lettering in Table 4. The values shown in yellow are values that would be lower than 0.56, but the formula assigns a lower value of F = 0.56. That would correspond to a Common wall area of 800 sq. ft. for an

Table 4: F sample values – Common wall areas greater than zero

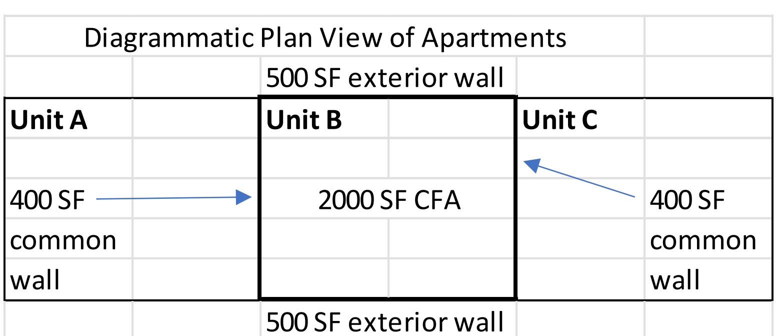
	$AF = A_s \times FA \times F$		
Above Grade Thermal Boundary Wall		Common wall area	**F**
1000		0	1.0
1000		500	0.7
1000		750	0.6
1000		800	0.56
1000		1000	0.56
1000		3000	0.56
1000		10000	0.56
1000		100000	0.56
0.56 is as low as the F - value is required to go.			

apartment with 1000 sq. ft. of exterior walls. An illustration is provided in Figure 1 for reference. This is not that unusual of an occurrence and could be quite common where there are rows of apartments with two exterior walls and two common walls. In Figure 1, the common wall area of 800 sq. ft. is evenly distributed with 400 sq. ft. on each side, and the 1000 sq. ft. of exterior walls is also evenly distributed on either side of the building.

This arrangement is not unusual in the real-world, and therefore the values that the variable F could take on will vary between 1.0 and 0.56, with values near 0.56 probably quite common. Having values less than one (1) multiplying the A_s variable will lower that value, which will reduce the glazing area that the modeler may be able to use as the Reference Design.

Bear in mind, as for the FA variable, this reduced A_s value is then what the modeler is required to use for the Reference design, (AF) as compared to their "As proposed" amount of glazing.

Figure 1: Diagram of Apartments with common walls



Combined FA and F effect on A_s and AF

Although unlikely, but not impossible, there could be an apartment building that has a combination of below grade walls and common walls, and the formula recognizes this, as both FA and F are in the formula. In cases where both FA and F are less than one (1), you have a "percent times a percent" which always leads to an even smaller value that will reduce the numerical value that AF ($AF = A_s \times FA \times F$) takes on. In the values in the sample Tables we have, if we take an FA value of 0.8, indicating 500 sq. ft. of boundary wall area, and an F value of 0.56, indicating 800 sq. ft. of common wall, we get the following equation to solve:

$$AF = A_s \times FA \times F$$
$$AF = A_s \times 0.8 \times 0.56$$
$$AF = A_s \times 0.448$$

One can see from the above example, that the A_s value can be reduced to less than half of its starting point. Bear in mind, this AF value arrived at via the formula $AF = A_s \times FA \times F$ is just a comparison point; it is not inferring that reference design building will get built with the reduced glazing area; it is only the value that the proposed modeled building has to compare itself and its performance to.

The above exercises and illustrations are intended to help the reader (and the analyzer) understand the process to be used if this code path is used, whether for the base code language or for the proposed code language.

Proposed Code Language – Formula analysis

With the proposed code language path, the same path must be taken when footnote "h" is invoked, and that whenever there is a building with below-grade conditioned basements or R-2 and R-4 residences and townhouses, the reference glazing amount is subject to the following formula:

$$AF = A_s \times FA \times F$$

And, as illustrated previously, there are many cases where the As value will be reduced below the 15% base model assumption for comparison purposes with the modeler's Proposed glazing sq. ft. value.

Although the proposed code language sets two new conditions, shown below:

Figure 2: Conditions imposed by proposed code language

[h] For residences with conditioned basements, R-2 and R-4 residences and townhouses, ~~the following formula shall be used to determine glazing area~~: the revised reference design total glazing area shall be the lesser of :
(1) Proposed glazing area
(2) The revised reference design total glazing area calculated using the following formula: AF = As X FA X F where:

The path that must be followed I believe ends up always subjecting the building in question to the formula of $AF = A_s \times FA \times F$, and the modeler must choose the lesser of the two conditions, which will almost surely be the value adjusted by the formula $AF = A_s \times FA \times F$. This would be the same path as the existing code language; therefore, I could not find a practical difference in results this proposed code change will bring between two buildings.

During the Building Code Council quarterly meeting, the proposer discussed a desire to change the language such that it was not so difficult to model a project with small units (R-2, R-4 or townhouses) such that the model will yield a design that exceeds the prescriptive code and therefore may be eligible for financial incentives from a utility. In small apartments, there may be very limited exterior walls, and the reality is much of this wall may be taken up with glazing (fenestration) that also doubles as the minimum manual ventilation requirements prescribed by the code, and the emergency opening requirements prescribed in other parts of the code. With the reference building having a reduced glazing area, all other components held equal, it would be difficult to differentiate a modeled building from the reference building where the reference building has a AF value that is reduced due to the FA or F factors.

With smaller buildings in general, it is difficult to reduce insulation in one area and try to make up for it elsewhere, simply because there is not enough area of the already compliant areas to make up the deficiency in other areas.

Other issues

Variable ambiguity

In looking into the original question, there are variables that are not well-defined in Table R405.5.2(1), so some assumptions needed to be made to pursue the math. The main assumption is that when Table R405.5.2(1) refers to glazing, the assumption is this is meaning the actual glass and the frame, thus it is "fenestration" as referred to in the prescriptive code. There is no other section in Table R405.5.2(1) that categorizes the frame of fenestration, and this can be a considerable source of heat transfer or lack of heat transfer for many high-performing windows and doors, so it cannot be ignored.

Buildings affected

The number of houses affected by this formula is unknown. One can create the building size that it is affected by, or rather the glazing percentage, but it is unknown how many real-world buildings fit this scenario whereby:

1. The permit holder chooses to use the Simulated performance Alternative, since the prescriptive methods does not have this issue.
2. The proposed building ends up requiring more glazing be modeled than the reference building

It is likely a "small percentage times a small percentage" which produces an even smaller product, but any future analysis may need to investigate this further.

Summary

The expectation of doing this analysis was to arrive at a value of glazing sq. ft. for the reference design using the existing code language and compare it to the value of glazing sq. ft. for the reference design for the proposed code language, and determine the difference, if any, and apply the costs and savings to this. As the language is written, the proposed language does clarify the path and variables better than the existing language, but I don't think it changes the outcome in the scenario that the proposer I believe was seeking. It is possible I am misunderstanding the intended meaning of the proposed language, or the maybe the intent itself. This could be worked out in the future if the proposer wishes to continue with the proposal.

Prepared by NCDOI Staff – Dan Dittman