Interim Report

Review and Consider Possible Technical Changes to section 553.9065, Florida Statutes

Submitted to
Department of Business and Professional Regulation
Office of Codes and Standards
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Tallahassee, FL 32399
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Prepared by:
Rob Vieira, Chuck Withers, Philip Fairey,
Florida Solar Energy Center

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University of Central Florida's Florida Solar Energy Center (FSEC)
Prepared by: Rob Vieira, Chuck Withers, Philip Fairey, Florida Solar Energy Center

1. Introduction

Pursuant to section 553.9065, Florida Statutes, the FBC has been tasked with reviewing and consideration of the legislative requirements for unvented attic as outlined in section 553.9065, Florida Statute for the purpose of providing technical changes and reporting such changes to the Legislature by December 31, 2024.

Section 553.9065 provides thermal efficiency standards for unvented attic and unvented enclosed rafter assemblies.

(1) Unvented attic and unvented enclosed rafter assemblies that are insulated and air sealed with a minimum of R-20 air impermeable insulation meet the requirements of sections R402 of the Florida Building Code, 8th Edition (2023), Energy Conservation, if all of the following apply:
- (a) The building has a blower door test result of less than 3 ACH50.
- (b) The building has a positive input ventilation system or a balanced or hybrid whole-house mechanical ventilation system.
- (c) If the insulation is installed below the roof deck and the exposed portion of roof rafters is not already covered by the R-20 air-impermeable insulation, the exposed portion of the roof rafters is insulated by a minimum of R-3 air-impermeable insulation unless directly covered by a finished ceiling. Roof rafters are not required to be covered by a minimum of R-3 air impermeable insulation if continuous insulation is installed above the roof deck.
- (d) All indoor heating, cooling, and ventilation equipment and ductwork is inside the building thermal envelope.

FSEC was contracted to conduct a literature review of available field study and research papers published on the subject of moisture in sealed attics and evaluate the impact of the thermal efficiency standards for unvented attic of section 553.9065, Florida Statutes on moisture within sealed attics, and the energy use of Florida homes relative to the provisions of the Prescriptive Compliance Method of the 8th Edition (2023) Florida Building Code, Energy Conservation – Residential Provisions.

2. Scope of Work:

a. Literature Survey

The objective of this task is to review available research literature particularly as it applies to moisture in sealed attics. This review will help provide guidance for various installations that may become more prevalent with the new legislation.

- FSEC shall conduct a literature review of available field study and research papers published on the subject of moisture in sealed attics.
- FSEC shall provide a summary of the literature survey outlining the recommendations and conclusions of each research project reviewed.

b. Evaluate the energy performance of the thermal efficiency standards for unvented attic as depicted in section 553.9065, Florida Statutes

The objective this task is to evaluate the impact of the thermal efficiency standards for unvented attic of section 553.9065, Florida Statutes on the energy use of Florida homes relative to the provisions of the Prescriptive Compliance Method of the 8th Edition (2023) Florida Building Code, Energy Conservation – Residential Provisions.

- FSEC is performing simulations to quantify the energy use differences between the unvented attic energy measures of section 553.9065, Florida Statutes, and that of the prescriptive compliance method of the 8th Edition (2023) Florida Building Code, Energy Conservation – Residential Provisions.
- The analysis will record the expected change in energy use via a matrix of 120 or more simulations that vary residence types (one-story, two-story, flat), location, duct tightness, mechanical ventilation, roof pitch, and ceiling and roof insulation levels.
- Based on the simulation results we will determine the likely predicted average change in energy use due to the new legislation.

c. *Summarize findings and make recommendation in a final report to the Florida Building Commission.*

- FSEC will present results in a final report and, if requested, a presentation to the FBC Energy TAC or full commission.

3. Literature Review Progress

This section will begin with a general synopsis of research literature shown in this section with a particular focus on unvented attics and attic moisture control in hot and humid climates. Following the general synopsis are selected publications included with a summary. The publications recognized within the general synopsis have reference details that can be found at the end of this section. There are some other studies related to energy use in attics that will be added for the final report.

General Synopsis:
The literature search found that unvented attic research began getting published around the early 1990's. An early focus was on simulated space conditioning energy impacts and thermal impacts upon roof materials. Parker et al. 1991, Beal et al. 1995, and Rudd 1996. The potential benefits of limiting condensation potential in attics by unventing attics in hot humid climates shows up in a 1993 HUD research report. In research on attic moisture problems in manufactured homes, TenWolde and Burch 1993 recommended that roof cavities not be ventilated in hot humid climates as a means to limit condensation in attics. Published research found from the period covering 2000 to 2022 focused on more simulation as well as measured moisture in attic air and attic materials in small studies in real homes. The most recent research in hot and humid climates has involved measurements of attic air and attic wood moisture content in occupied homes over a period of one to three years. Open cell insulation has been the most common option used in Florida and happened to be the material used in the published research found. The consensus of all studies focused on hot and humid climates was that attic wood moisture content (WMC) was at acceptable levels in unvented attics with spray foam applied to roof sheathing. WMC spikes over 20% in properly installed spray foam attics were rare and did not occur long enough to result in mold or moisture issues. Some research has found elevated attic air RH over 60%. One publication from a specific organization recommended using conditioned air into the unvented attic with open cell spray foam as one method that may improve attic air humidity control within the attic. This practice is part of International Residential Code 2021 R806 only applying to when air-permeable insulation is applied against the roof sheathing within the attic with some exceptions. Some builders resort to installing stand-alone dehumidifiers into unvented attics to control attic RH. One study (Rudd et al. 2005) found that this practice may significantly increase the home energy use. Two homeowners in this study having stand-alone dehumidifiers in the attic complained of high energy consumption, however accepted it since the attics were maintained very dry (Ruud et al. 2005 pg. 19).

Following here are specific studies along with a brief summary. Reference details on the aforementioned studies and industry resources on wood moisture control guidance are at the very end of this report section.

Withers, C and. E. Martin. "Seasonal Moisture Impacts on Roof Deck Moisture in Unvented Attics in North Florida". Published ASHRAE 2022 Thermal Performance of the Exterior Envelopes of Whole Buildings XV International Conference; pp.649-657. Peer reviewed. Presented at the Buildings XV Conference December 7, 2022. Available online as: FSEC-PF-1275-23
https://publications.energyresearch.ucf.edu/wp-content/uploads/2023/04/FSEC-PF-1275-23.pdf

This was a three year study of attic moisture in six new (newer homes no more than 2 years old at start of monitoring) unvented attic homes in north central and north east Florida. Two new homes with conventional vented attics were also added to this study during the last two years. Low density open-cell spray foam attics research was funded by The American Chemistry Council. Seasonal outdoor temperature had greater influence on roof sheathing WMC% than other measured variables such as indoor moisture, house, attic, or duct air tightness. Winter weather induced the highest roof sheathing WMC. Winter low temperature cold front events typically dropped into the 40's °F however a few events dropped into the 30's °F. "*The WMC was at its highest levels (between 15% - 20% WMC) during the colder periods when there was also less direct solar radiation. The WMC dropped to less than 15% WMC by March and remained between 10%- 15% WMC until the next winter*." Some homes had higher winter WMC in the first year than following years. This was noted as it was possibly due to greater material moisture levels within new construction materials, such as concrete, which takes several months to release moisture. For comparison to the unvented roofs, roof deck moisture was also measured in two conventionally vented attics in north east FL. "*The daily average moisture content of the vented attic roof decks rarely exceeded 10% WMC through all seasons*."

Five unvented homes were shingle and one unvented home had a metal roof. The metal roof had notably lower WMC all year round compared to the other shingle roof homes. This was particularly noticeable during cold weather compared to an asphalt shingle roof and demonstrated that the type of roof covering can also influence attic moisture and specifically roof deck WMC. During similar cold weather conditions, a shingle roof cooled down about 26°F colder than the metal roof deck (north slopes) and the shingle roof sheathing WMC averaged 3.6% WMC greater than the metal covered roof sheathing.

Generally attic moisture was controlled well, however, some measurements found that the longer the cold weather event, the more the daily average sheathing WMC% trended upward. One measurement location in first year study during very cold weather lasting a few weeks had WMC near 30% which would damage wood if prolonged. It was determined that some small thin cuts in the foam around sensor location not adequately sealed permitted more moisture to move much more readily than non-disturbed foam. This site indicated the importance of protecting foam insulation from punctures or other damage. The prolonged cold weather also hinted that homes with open cell foam on roof sheathing in regions that more commonly experience longer uninterrupted cold weather for several weeks in a row may have roof deck WMC that exceeds 20% during that time.

Martin, E. and C. Withers. "Survey of Unvented Attics in Climate Zones 2" Florida Solar Energy Center, FINAL REPORT To Stephen Wieroniey, American Chemistry Council, March 17, 2021. FSEC-CR-2106-21
https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/02/FSEC-CR-2106-21.pdf

This 102 page final report covers the three year study of 6 unvented attic homes and 2 vented attic homes conducted in north central and north east Florida. This report offers much greater details of the research paper Withers and Martin 2022 previously covered.

Withers, C., Fenaughty, K., and Sonne, J. Measured Energy and Moisture Performance Impacts from Vented and Unvented Attic with Insulation On Top of Ceiling in the Hot Humid Climate Zone. Published in ACEEE 2020 Summer Study on Energy Efficiency in Buildings Virtual; Conference Proceedings pp 1-415 – 1-430. Peer reviewed. Conference August 17-21, 2020.
https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/05/FSEC-PF-1264-21.pdf

Research funded by the Florida Building Commission and conducted in an unoccupied manufactured test house facility measured indoor and attic air environment with conventional attic vents and without vents. Internal sensible and latent loads were generated to mimic occupancy. **R30 blown cellulose attic insulation remained on the ceiling and the roof deck remained uninsulated**. Central system supply ducts with R11 insulation jacket were located in the attic. "*The project showed unvented attic with attic ducts was warmer and had an 8% increase in cooling energy compared with vented attic with attic ducts, and had substantially drier attic space than vented attic. Moisture content and relative humidity levels were acceptable during all testing; however there was significant moisture increase with the unvented attic tests during cold weather periods.*"
"*Material moisture levels under all test configurations stayed below the upper target limit of 20% WME under the weather test conditions; however roof deck WME nearly approached 20% during short periods of the coldest weather. The trend of higher roof deck moisture occurring during cooler weather shows cause for not sealing attic vents in the configuration tested, especially if more heating is required than in the cooling-dominated climate where these tests were conducted. The vented attic was moister in summer and drier in the winter, when attic materials are more susceptible to moisture problems. Comparison*

between attic vented and attic vents sealed during two similar cool days found the roof deck wood moisture content was 33% higher during the sealed attic vent configuration peak WME value."

Prevatt, D., A. Viswanathan, W. Miller, P. Boudreax, S. Pallin, and R. Jackson. "Phase II Analytical Assessment of Field Data for Sealed Attics in Florida Climate Zones 1 and 2 – Predicting Moisture Buildup in Roof Sheathing." Final Report Submitted to Florida Building Commission, June 2017

Prevatt 2017 studied roof deck WMC in a sample of four unvented attic homes sealed with low density spray foam over a period of one year. Two of these homes were located in south Florida and two were in central Florida. The winter conditions were very mild during the monitoring period with the coldest outdoor temperatures only reaching 60F to 65F. Data presented showed WMC below 15% for three homes all year with modest increases during winter. The fourth home in Gainesville, Florida had WMC below 15% for almost the entire year except during two separate periods during the January and February 2017 period when WMC spiked up to about 19-20%. The spikes generated limited discussion, but no conclusions were drawn about the cause, primarily since this home was occupied by seasonal residents. The occupancy status throughout the monitoring of this home was unknown. Prevatt 2017 noted within the report that the colder weather coincided with the spikes but, later concluded that the cause was unknown and presumed to be due to occupancy habits without any evidence to support the presumption.

Lstiburek, J. "Ping Pong Water and the Chemical Engineer" Building Science Insights BSI-016. Building Science Corporation. October 2016. https://buildingscience.com/documents/building-science-insights-newsletters/bsi-016-ping-pong-water-and-chemical-engineer

This document provides important description on how water vapor is higher at the top of unvented attics which can result in elevated attic air humidity. The process of diurnal adsorption and desorption of moisture from the roof sheathing passing through open cell low density spray foam and to attic air is described from a chemical engineering perspective. "*When they* (water molecules) *exit the foam they are a little warmer than the attic air column and the surface of the foam has a higher molar concentration of water, so, they ride the buoyant film of gas skimming up along the surface of the foam – buoyant because it is both warmer and less dense...*". The process repeats nightly and results in higher moisture content at peak and stratification of moisture within the attic. The term "ping-pong" is coined to describe the nightly cycle of moisture movement adsorption, desorption, and thermal climb. The author claims this phenomena is not observed with close cell spray foam on roof sheathing as it has very low moisture permeability.

The conclusion of this document is that open cell spray foam is acceptable to use if the attic has some conditioned air to reduce moisture build up. In climate zones 1, 2, and 3 it was recommended that conditioned air be provided to the unvented attic at a rate of 50 cfm per 1000 ft^2 of ceiling.

The recommendation for conditioning unvented attics eventually became part of International Residential Code, however the provision for 50 cfm / 1ksf of ceiling only applied if air-permeable insulation was applied against the underside of roof sheathing. IRC 2021 does not require conditioned air into unvented attic where air-impermeable insulation, such as spray foam, is applied against the roof sheathing.

This opens up the question whether unvented attics with open cell spray foam on sheathing in Climate Zones 1, 2, and 3 should be conditioned for better moisture control. In the balance, there would be an increase in space conditioning energy use from providing conditioned air into the attic.

Excerpt from IRC 2021 R806:
5.2 In Climate Zones 1, 2 and 3, air-permeable insulation installed in unvented attics shall meet the following requirements:
...
IRC 2021 Section R806 5.2.10 Where air-permeable insulation is used and is installed directly below the roof structural sheathing, air shall be supplied a t flow rate greater than or equal to 50 CFM (23.6L/s) per 1,000 square feet (93m2) of ceiling. The air shall be supplied from ductwork providing supply air to the occupiable space when the space conditioning system is operating. Alternatively, the air shall be supplied by a supply fan when the conditioning system is operating.

Exceptions:

1. *Where both air-impermeable and air-permeable insulation are used, and the R-value in Table 806.5 is met, air supply to the attic is not required.*
2. *Where only air-permeable insulation is used and is installed on top of the attic floor, or on top of the ceiling, air supply is not required.*

Colon, C. 2011. New Construction Builders Challenge: Sealed Attics and High Efficiency HVAC in Central Florida. Florida Solar Energy Center, Cocoa, FL: https://publications.energyresearch.ucf.edu/wp-content/uploads/2018/06/FSEC-PF-454-11.pdf

This research was funded through U.S. Department of Energy Building America Program and involved study of new unoccupied model home built in 2010 with R27 open cell spray foam on the underside of the roof deck creating an unvented attic in Rockledge, Florida. Measurements of attic air near peak and at mid attic height indicated generally good indoor attic RH levels with daily average RH maintained below 60% RH. Data showed diurnal RH pattern with peak RH during afternoon and lowest RH during sundown hours. Highest attic RH was during May and June 2010 and then again similar values March and April of 20ll.

Forest Products Laboratory. 2010. “Wood handbook—Wood as an engineering material.” General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr190.pdf

Publication of 509 pages is comprehensive document covering mechanical, structural, and fastening aspects of using wood in buildings. Chapters 13, 14, and 15 cover wood moisture control, biodeterioration of wood and wood preservation. Guidance to maintain WMC below 20% to avoid mold, stain and decay. Indicates serious wood decay begins when WMC maintained 30% or more for long period of time.

Other documents provide some similar information. Some may be described further in the final report.

APA – The Engineered Wood Association. “Water Vapor Permeance of Wood Structural Panels and Wood Wall Construction”. Engineered Wood Systems APA, Tacoma, Washington. J450, February 2009. http://www.norbord.com/na/cms/wp-content/uploads/Moisture%20Vapor%20and%20Perms%20J450.pdf

APA – The Engineered Wood Association. “Moisture Control in Low Slope Roofs”. Engineered Wood Systems APA, Tacoma, Washington. EWS R525B, January 1999. https://www.buildgp.com/DocumentViewer.aspx?repository=bp&elementid=3208

Four page guidance document mentions considering use of insulation above the wood deck to maintain wood temperatures above the dewpoint in attic when low design temperatures or high interior humidities are expected.

Parker, D.S., P.Fairey, and L. Gu, 1991. A stratified air model for simulation of attic thermal performance. Insulation Materials: Testing and Applications, Vol. 2, ASTM STP 1116, R.S. Graves and D.C. Wysocki, eds. Philadelphia: American Society of Testing and Materials. https://publications.energyresearch.ucf.edu/wp-content/uploads/2018/06/FSEC-PF-226-91.pdf

Beal, D., and Chandra, S. 1995. Side by side testing of four residential roofing and attic ventilation systems. FSECCR-822-95. Florida Solar Energy Center, Cocoa, Fla.

Rudd, A.; Lstiburek, J.; Eng, P.; Ueuno, K. (2005). Residential Dehumidification Systems Research for Hot-Humid Climates. NREL/SR-550-36643 National Renewable Energy Laboratory, Golden, CO http://www.buildingscience.com/documents/bareports/ba-0219-residential-dehumidifications-systems-research-hot-humid-climates

Rudd, A., 1996. Vented and sealed attics in hot climates. Contract Report submitted to Building Science Corporation,Westford, Mass., and the U.S. Department of Energy, 30 October. Florida Solar Energy Center, Cocoa, Fla., FSEC-CR-911-96.

Rudd, A., and. J. Lstiburek. 1998. ”Vented and Sealed Attics in Hot Climates”. Published ASHRAE Transactions Volume 104, Part 2. https://buildingscience.com/sites/default/files/document/rr-0981_vented_sealed_attics.pdf

4. Simulation Progress

A matrix of planned simulation runs has been developed. This matrix of 240 simulations will allow comparisons to reflect each of the proposed elements of 553.9065 changes as well as the whole 553.9065 change.

Table 1. Parameters that may vary during simulation analysis. Green type shows current R402 requirement. Red type shows new or repeated values in proposed change.

Current Prescriptive R402 Code Planned Simulations				Total
Home Type	2000 ft2 single story detached	2400 ft2 two-story detached	Multi-family unit	3
Cities	Tallahassee	Miami		2
Duct Leakage	Qn_{out}= 0	Qn_{out} =0.04		2
Mechanical Ventilation	None			1

Roof Pitch	4 in 12	8 in 12		2
Roof/Ceiling Insulation	R0/R38 (Tallahassee) or R0/R30 (Miami), Vented attic	R38/R0 (Tallahassee) R30/R0 (Miami), Unvented attic		2
House Air Leakage	7 ACH50			1
Total Current Code Simulations				**48**

Proposed Code Change Analysis Simulations –Unvented Attic					Total
Home Type	2000 ft2 single story detached	2400 ft2 two-story detached	Multi-family unit		3
Cities	Tallahassee	Miami			2
Duct Leakage	$Qn_{out}= 0$	$Qn_{out} =0.04$			2
Mechanical Ventilation	100% Whole house supply system – vented to ASHRAE 62.2 standard	Hybrid: Central Fan Integrated w make up, vented to ASHRAE 62.2 standard	Balanced system, vented to ASHRAE 62.2 standard	Enthalpy Ventilation Recovery (ERV) vented to ASHRAE 62.2 standards	4
Roof Pitch	4 in 12	8 in 12			2
Roof/Ceiling Insulation	R20/R0 (Tallahassee) or R20/0 (Miami)	R20/R19 [1] (Tallahassee) R20/R19 (Miami)			2
House Air Leakage	3 ACH50			1	
Total Proposed Change Analysis Simulations					**192**

The base case characteristics of the prescriptive buildings modeled are summarized in Table 2. For this project the multi-family unit modeled is only a top floor unit unlike previous studies that also modeled non top-floor units.[2] The legislative change should not affect units without thermal connection to the roof/attic.

[1] The R19 ceiling insulation is just an alternative, not a requirement of the legislation.

[2] Sonne, Jeff, Rob Vieira, "Florida Building Code, Energy Conservation, 8th Edition (2023) vs. 2021 International Energy Conservation Code Residential Stringency Analysis," FSEC-CR-2124-24

Table 2. Characteristics of base house simulations compliant with Florida 8th Edition Prescriptive Compliance Path

Component	Climate Zone 1 2023 FBC-EC	Climate Zone 2 2023 FBC-EC
Conditioned floor area (ft^2) (one story / two story / multi)	2,000 / 2,400 / 1,200	2,000 / 2,400 / 1,200
Floor Type	SOG/SOG/neighbor	SOG/SOG/neighbor
Floor perimeter *R*-value	0	0
Wall type	Wood Frame	Wood Frame
Wall insul. *R*-value	13	13
Wall solar absorptance	0.75	0.75
Common wall area (multi-family only)	720	720
Window area (ft^2) (one story / two story / multi)	300 / 360 / 120	300 / 360 / 120
Window *U*-factor	0.5	0.4
Window SHGC	0.25	0.25
Roofing material	Comp. Shingles	Comp. Shingles
Roof solar absorptance	0.92	0.92
Attic ventilation	Vented 1/300	Vented 1/300
Ceiling insul. *R*-value	30	38
Envelope ACH50 (air chng/hr @ 50pa)	7	7
Equipment and Effic. Cooling / Heating	SEER2 14.3 / Elec. Strip	SEER2 14.3 / HSPF2 7.5
AHU location (one story / two story / multi)	Garage / Garage / Cond. Space	Garage / Garage / Cond. Space
Duct insul. *R*-value	8 / 8 / 8	8 / 8 / 8
Duct location (one story / two story / multi)	Attic /Attic/Attic	Attic /Attic/Attic
Duct leakage	Qn_{out}= 0.04	Qn_{out}= 0.04
Leakage split Supply-Return	50%-50%	50%-50%
Supply Duct Area ft^2	400/240[3]/240	400/240/240
Return Duct Area ft^2	100/60/60	100/60/60
Heating / Cooling set points (°F)	72 / 75	72 / 75
# of bedrooms (one story / two story / multi)	3 / 4 / 2	3 / 4 / 2
Water heater size (gallons)	50 / 50 / 40	50 / 50 / 40
Water heater UEF (electric)	0.93	0.93
Water heater location (one story / two story / multi)	Garage / Garage / Cond. Space	Garage / Garage / Cond. Space
Water heater pipe insulation *R*-value	3	3
Water heater heat trap	Yes	Yes

[3] Fifty percent of supply and duct area are assumed in conditioned space for two-story house.. Only the portion in attic are modeled.

A limited number of simulations have been run. Figure 1 shows the change just from going from R38 ceiling insulation to R20 roof insulation without any change in home air leakage or adding mechanical ventilation. On the left is with the prescriptive 0.04 duct leakage to outside. The comparison on the right is if the duct leakage were 0 in both attic configurations.

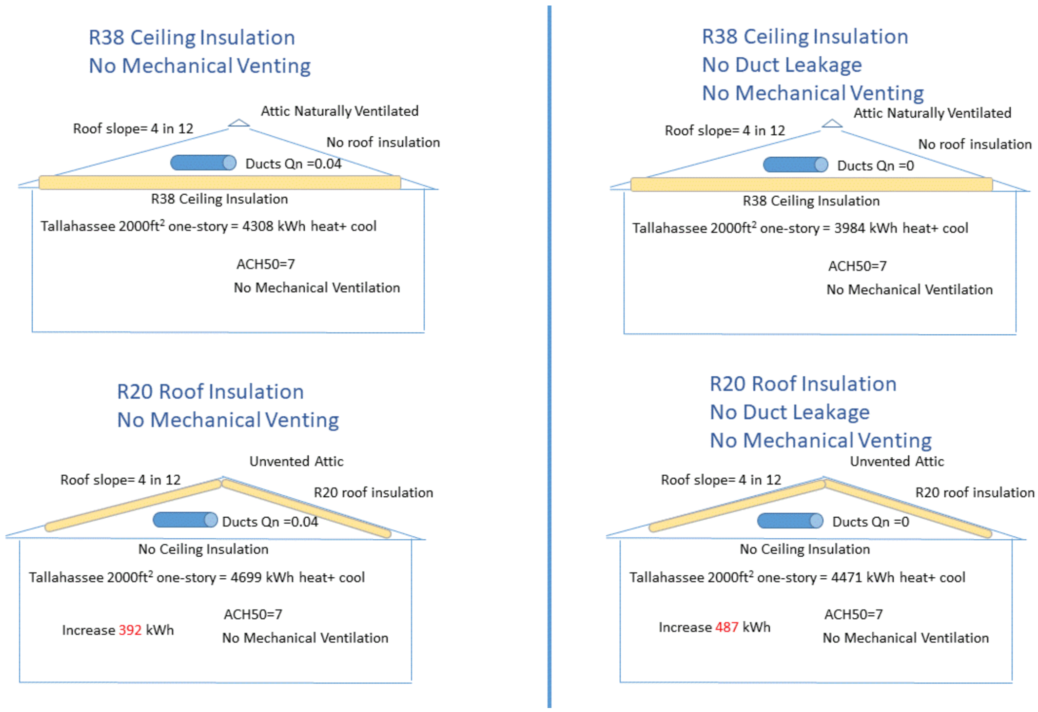

Figure 1. Illustration showing change in energy use from FBC, Energy Conservation R402 prescriptive code with conventional ceiling insulation to unvented attic with R20 rafter insulation for two different levels of duct leakage for Tallahassee simulated one-story, 2000 ft2 house. Qn_{Total} *=0.04 is maximum tested duct leakage allowed under the prescriptive code and 0 is no duct leakage.*

Figure 2 shows the impact when we compare the current prescriptive code air leakage of 7 ACH50 and no mechanical ventilation to the proposed change to 3 ACH50 under four different mechanical ventilation scenarios. This is the middle series of bars on the chart. The top series is with R20 at the attic and R19 insulation at the ceiling and the same requirements. This scenario should meet current code requirements and uses about the same amount of energy as the basecase while adding 62.2 level of ASHRAE ventilation. The difference in kWh is shown in Figure 3. Depending on whole house mechanical ventilation system the energy use increase for the proposed change was simulated as 293 to 564 kWh in Tallahassee.

Figure 4 and 5 show similar graphs for simulations of a 2000 ft^2 home in Miami. The prescriptive code only calls for R30 insulation in Florida climate zone 1. Thus the differences in energy use are smaller than in Tallahassee.

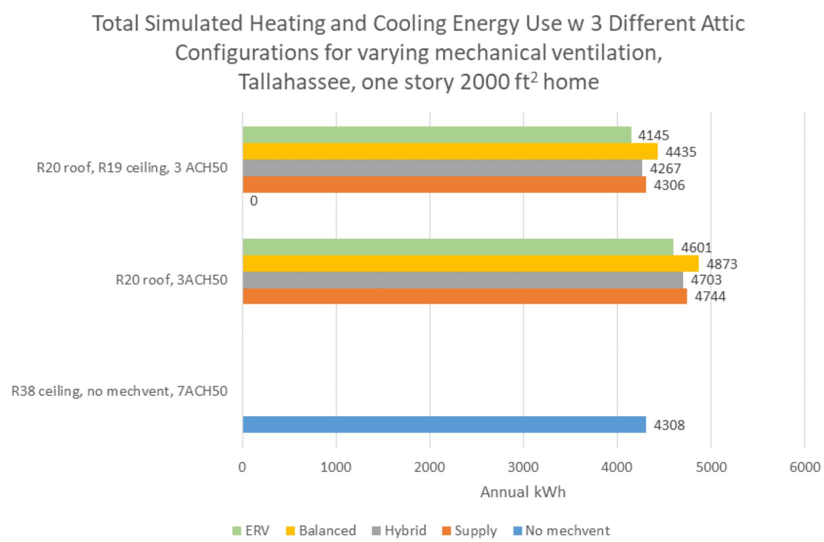

Figure 2. The bottom bar is current code with R38 ceiling insulation. The middle set of charts is proposed change showing increase in energy use regardless of ventilation strategy. Top bar shows an alternative with roof and ceiling insulation; energy use is projected to be similar for this case as the R38 ceiling insulation case.

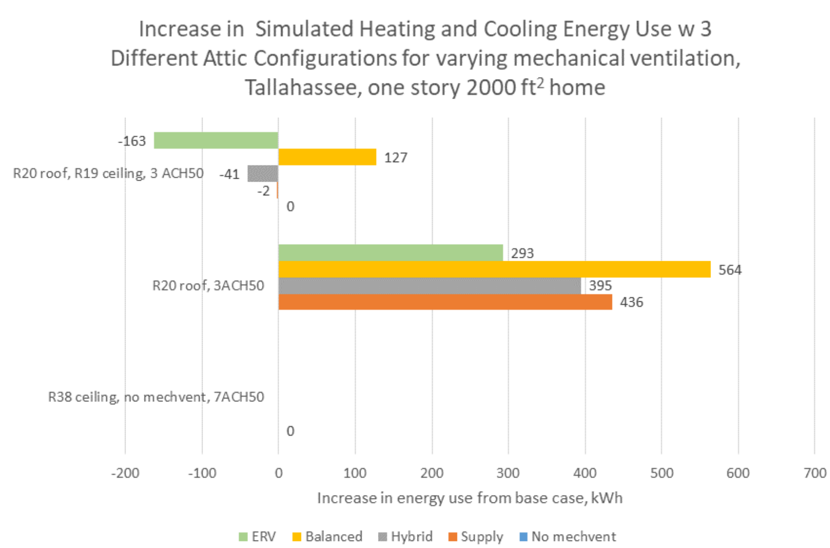

Figure 3. This figure depicts the increase (negative values are savings) in energy use for proposed and alternative changes versus the base case for Tallahassee.

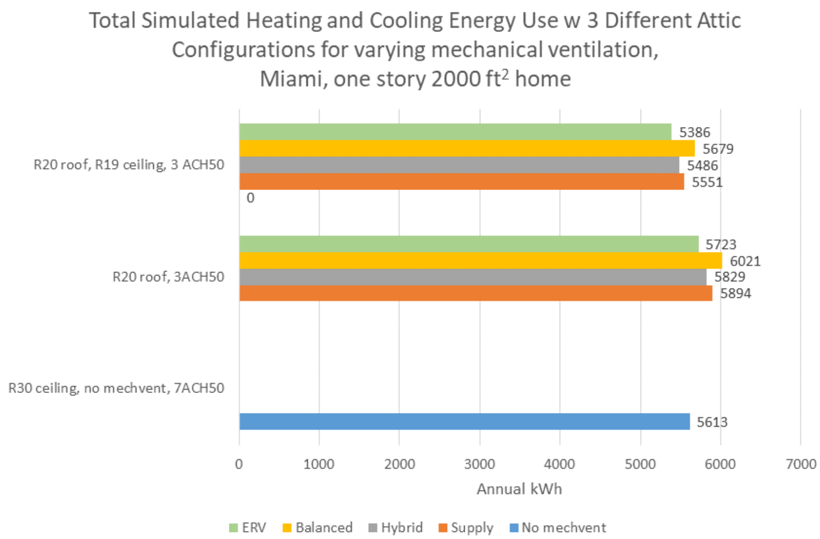

Figure 4. The bottom bar is current code with R30 ceiling insulation. The middle set of charts is proposed change showing increase in energy use regardless of ventilation strategy. Top bar shows an alternative with roof and ceiling insulation; energy use is projected to be less for this case than the R30 ceiling insulation case.

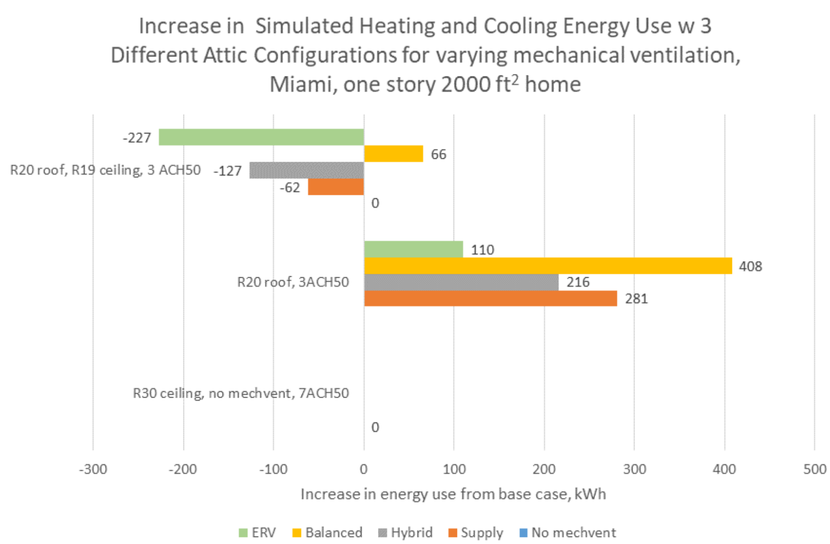

Figure 5. This figure depicts the increase (negative values are savings) in energy use for proposed and alternative changes versus the base case for Miami.

The full set of results will be presented in the final report.