Draft Report: Development and Implementation of an Improved Residential Energy Code for North Carolina

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Introduction

Appalachian State University's Department of Technology and Energy Center and Mathis Consulting received a grant to make the North Carolina Energy Efficiency Code 30% more efficient than the 2006 International Energy Efficiency Code. The project was broken down into the following tasks:

Phase One: Develop and Implement Strategy for Improved Energy Code Approval

Task 1: Expand/hold meetings of the North Carolina Energy Code Task Force
Task 2: Develop the proposed North Carolina Energy Code
Task 3: Develop informational materials and economic analysis regarding proposed code
Task 4: Presentation to key target audiences
Task 5: Work with the Energy Code Subcommittee to gain approval of the proposed code
Task 6: Work with the Building Codes Council to approve the improved energy code
Task 7: Submit Periodic and Annual Reports

Phase Two: Assist in Implementation of the Improved Energy Code

Task 9: Monitoring Final Code Development
Task 10: Development of Continual Success Program
Task 11: Code Training and Enforcement
Task 12: Energy Code Outreach
Task 13: Quarterly and Annual Reports

The Project Team Consisted of the Following Members:

Appalachian State University –

Jeff Tiller, Principle Investigator
Bruce Davis, Building Scientist
Andrew Windham, Research Engineer
Erica Porras, Research Engineer
Anna Erwin, Research Scientist
Bryan Johnson, Research Scientist
Sean Gray, Research Scientist

Mathis Consulting –

Chris Mathis, President
Margie Meares, Senior Associate
Jonah Butcher, Senior Associate
Joan Walker, Associate

The Individuals who served on the Energy Code Subcommittee are as follows:

Tom Turner, Chairman of the Energy Code Subcommittee
Jeff Tiller, Department of Technology
Margie Meares, Mathis Consulting

Renee Hutchinson, American Institute of Architects
Dan Tingen, Contractor and Chair of the North Carolina Building Codes Council
Al Bass, Engineer
Robert Privott, North Carolina Home Builders Association
Hawley Truax , Z. Smith Reynolds
John Wiggins, Underwriters Laboratories
Paula Strickland, North Carolina Building Codes Council
John Roberts, IES Engineers
Kim Reitterer, North Carolina Building Codes Council
Douglas Brinkley, American Institute of Architects
Reid Conway, State Energy Office's Western Region
Billy Hinton, NC Department of Insurance
Dennis Maidon, Wake County Inspections Office
Chad Chandler, American Institute of Architects

The Target Stakeholders for the Project are as follows:

North Carolina Homebuilders Association
American Institute of Architects
Engineers
Insulation Contractors
Heating and Air Contractors
Glass Manufacturers and Window Manufacturers

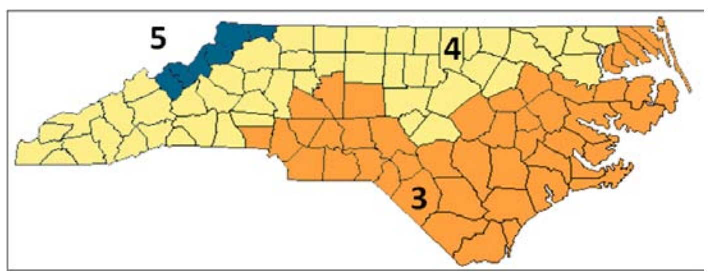
Summary of Benefits for North Carolina

The proposed measures that the project team studied had positive economic results. The average payback period for the combined measures ranged from 2.2 to 7.6 years, which is equivalent to a 14% to 47% annual rate of return on investment – an attractive range for future energy savings for home owners compared to initial costs of installation. In all cases, the measures provide a positive cash flow.

Over the 3-year code cycle from 2012 to 2015, 120,000 to 160,000 homes will be constructed in North Carolina. The net annual energy savings to the state will total $50 to 75 million dollars per year. In addition, the investment in efficiency measures will provide jobs for emerging companies, such as energy service firms, insulation companies, and HVAC contractors. The total additional investment would be in the range of $300 to $450 million, which would result in an additional 5,000 to 10,000 direct job-years over the next three years. Furthermore, many efficiency measures in the packages provide durable energy savings which will last years or decades after the initial pay-back period. This will help to keep the cost of electricity down as the North Carolina demand grows and contribute to solving peak-power demand challenges.

Methodology

International Climate Zone Designations in NC



The international climate zones were redefined for the 2006 International Energy Conservation Code. As can be seen from the table, North Carolina is now made up of three climate zones. The primary climate zones in the state, 3 and 4, have similar weather conditions in their two major growth areas surrounding Charlotte and Raleigh. One of the main goals for the proposed code provisions is to have the measures chosen be as consistent as possible throughout the state. This would avoid confusion for designers, builders, building supply companies, and code enforcement officials, which will increase compliance of the energy code.

Studying Code Documents

The first step of enhancing the residential portion of the 2006 International Energy Efficiency Code (IECC 2006) was to study the 2009 North Carolina Energy Efficiency Code (NC 2009), the IECC 2006, and the 2009 International Energy Efficiency Code (IECC 2009). In June of 2008, ASU and Mathis Consulting received a National Governor's Association grant to conduct trainings for code officials on the NC 2009 code. This combined knowledge was a helpful resource when developing proposals for increasing the efficiency of the IECC 2006 by 30%.

The project team began studying the current code and while doing this, found a proposal package to make the IECC 2009 30% more efficient than the IECC 2006. The package was not accepted by the International Code Council, but studying the features considered provided a productive starting place. A matrix was constructed to compare all the different standards for efficiency measure.

Software

After studying existing code languages and documents about increasing energy efficiency within a code, computer building modeling began. The project team decided to utilize REMRate to conduct energy models for a series of representative homes. REM Rate was chosen because it complies with National Home Energy Rating Standards and is the software developed for HERS providers. REM Rate has climate data programmed into the modeling software, determines heating, cooling, hot water, lighting, and appliance energy loads for new and existing single family and multi-family homes. The software is also programmed to determine if a home meets Energy Star, ASHRAE 90.2, tax credit, and IECC standards. This program is approved by RESNET.

Microsoft Excel was used for the data analysis portion of this study. A series of spreadsheets was developed to determine the weighted average of energy savings, payback period, and net benefits. The spreadsheets served as an analytical tool that was used by the project team throughout the project.

There were many different areas to assess when making decisions on how to make residential buildings in North Carolina 30% more efficient. Options considered included combinations of insulation, fenestration, mechanical equipment, air and duct leakage, as well as many others.

Homes Chosen

Initially, two homes were chosen for the study. These homes included an 1800 square foot, single story home with a crawl space and a 3500 square foot, two story home with a slab. This soon evolved to studying both homes and an additional 2500 square foot home. All three buildings were modeled with a crawl space and a slab. These homes were modeled in cities of climate zones three, four, and five to get a representative sample of North Carolina's climates. The majority of new homes in North Carolina, 98%, are located in zones three and four, so when determining energy savings, the numbers were calculated using a weighted average technique.

<u>1800 Square Foot Home</u>

The 1800 square foot home was chosen because it is a popular sized home for residential construction in North Carolina, and it is also the home of one the project team researchers. The home is one story, all electric with a heat pump, and is on a crawl space foundation.

Initially, the project team modeled the home primarily with a crawl space. After the study progressed, the team decided to model the home with a slab and a crawl space to gain more information about the energy usage of a house of this size.

<u>2500 Square Foot Home</u>

The project team decided to add to our modeling a 2500 square foot home following a couple meetings with the Energy Code Subcommittee. Although the original home was on a slab, the home was also modeled with a crawl space foundation. The home is built on crawlspace foundation and has a gas furnace. This home was eventually modeled with a heat pump and a furnace. Because this was the middle ground in regards to square footage, the home was also used for the additional study of varied window specifications, ceiling insulation values, a radiant barrier installation, and different building air leakage rates.

<u>3500 Square Foot Home</u>

The project team chose to use the 3500 square foot home from the beginning of the project. This is the largest home that we chose to model. ASU has experience working with home builders throughout North Carolina and had already conducted other research on this particular home. The home has a gas furnace, is on a slab, and is two stories. Initially, the home was modeled primarily with a slab, but as the project progressed, the home was also modeled with a crawl space.

Insulation and Fenestration

The project team studied the NC 2009 Energy Efficiency Code and the newly released IECC 2009 Energy Efficiency Code. Located below are tables, for each climate zone, that detail the insulation and fenestration standards for the current NC 2009 and the newly proposed IECC 2009. Throughout the process of the project, we streamlined the proposed changes through the three climate zones and used some standards proposed by the IECC 2009. Different standards between zones and enhancements that surpassed the IECC 2009 were implemented because of the unique geography of North Carolina and to ensure that we met 30% efficiency standards. In the following charts, the lighter green shade shows energy code measures that match the IECC 2009, while the darker green shade shows measures that exceed the IECC 2009.

Climate Zone Three

ZONE THREE	Code	Window U Factor	Skylight U Factor	SHGC	Ceiling R	Wood Wall R	Mass Wall R	Floor R Vented or Closed	Basement Wall R	Slab R	Crawl Wall R
	NC 09	0.40	0.65	0.40	30	13	5	19	none	none	5/ 13
	I 09	0.50	0.65	0.30	30	13	5	19	5/13	none	5/ 13
	30%	0.32	0.65	0.25	42	18 or 13+5	5	19	5/13	5 edge +2'	10/ 13

Zone 3 makes up 49% of North Carolina's new construction, and more changes were proposed in this zone than Zones 4 and 5. The most significant changes proposed were R-5 slab insulation, R-18 wall insulation, and R-42 ceiling insulation. *(Please note that the proposed change to R-42 may be revised to R-38.)* This climate zone includes the coast, which has a serious threat of hurricanes, so research was conducted regarding the status of impact resistance glass for our proposed window specifications. After communicating with Stock Building Supply, the Energy Code Subcommittee determined that impact resistance glass could have a maximum of a 0.40 SHGC. Zone Three also includes the city of Charlotte, which is the biggest city in North Carolina.

Climate Zone Four

ZONE FOUR	Code	Windo w U Factor	Skylight U Factor	SHG C	Ceiling R	Wood Wall R	Mass Wall R	Floor R Vented or Closed	Basement Wall R	Slab R	Crawl Wall R
	NC 09	0.40	0.60	0.40	38	13	5	19	10/13	5 edge +2'	10/ 13
	I 09	0.35	0.60	NR	38	13	5	19	10/13	10 edge +2'	10/ 13
	30%	0.32	0.60	0.25	42	18 or 13+5	5	19	10/13	10 edge +2'	10/ 13

Like Zone 3, Zone 4 also makes up 49% of North Carolina's construction. Raleigh, the capital of North Carolina, is located in Zone 4, as well as Asheville, Winston-Salem, and Greensboro. *(Please note that the proposed change to R-42 may be revised to R-38.)* The Solar Heat Gain Coefficient and U-Factor for the windows were also made more stringent to provide increased efficiency.

Climate Zone Five

ZONE FIVE	Code	Window U Factor	Skylight U Factor	SHGC	Ceilin g R	Wood Wall R	Mas s Wall R	Floor R Vented or Closed	Basement Wall R	Slab R	Crawl Wall R
	NC 09	0.40	0.60	0.40	38	18 or 13+5	5	30 Full [19]	10/13	10 edge +2'	10/ 13
	I 09	0.35	0.60	NR	38	18 or 13+5	5	30 Full [19]	10/13	10 edge +2'	10/ 13
	30%	0.32	0.60	NR	42	18 or 13+5	5	30 Full [19]	10/13	10 edge +2'	16/ 19

The remaining 2% of new residential construction in North Carolina takes place in Zone 5, the coldest, smallest climate zone in North Carolina. The changes to this climate zone are not as significant as Zones 3 and 4 because the insulation and fenestration requirements were already more stringent. The "NR" status for the SHGC rating was assigned because residential structures in Zone 5 do not have as many problems associated with solar heat gain as the warmer regions of the state. The "NR" status for the SHGC also allows for the building to benefit from solar heat gain during the longer heating seasons. *(Please note that the proposed change to R-42 may be revised to R-38.)*

<u>Upgrade Features – All Zones</u>

The table to the right shows the final insulation and window proposals made by the project team to the Energy Code Ad Hoc Subcommittee. In addition, the proposed code includes additional requirements for all zones such as provisions for increased air sealing along with required duct sealing and testing. Again, the team streamlined efforts when appropriate for the climate and to reach the 30% goal in energy savings. The most enhancements were made in Zone 3, but the other proposals in the other zones created significant changes when modeling the homes. *(Please note that the proposed change to R-42 may be revised for all zones to R-38.)* As noted previously, the lighter green shade shows proposed energy code measures that match the IECC 2009, while the darker green shade shows measures that exceed the IECC 2009.

All 30% Upgrade Features

Zone	Window U Factor	Skylight U Factor	SHGC	Ceiling R	Wood Wall R	Mass Wall R	Floor R Vented or Closed	Basement Wall R	Slab R	Crawl Wall R
3	0.32	0.65	0.25	42	18	5	19	5/13	5 edge +2'	10/ 13
4	0.32	0.60	0.25	42	18	5	19	10/13	10 edge +2'	10/ 13
5	0.32	0.60	NR	42	18	13	30 Full [19]	10/13	10 edge +2'	16/ 19

Mechanical Equipment

When the project team initiated its analytical efforts, it saw significant improvements when the efficiencies of mechanical equipment were increased. In addition, measures such as solar water heating equipment, higher furnace efficiencies, and higher seasonal energy efficiency ratio (SEER) for heat pumps were considered. Although these measures proved to save up to 15% of the energy, the team was cognizant that it would be very difficult to institute an individual state efficiency standard for mechanical equipment. After meeting with the Energy Code Subcommittee and hearing requests for further analysis, the project team proposed efficiency option packages that included higher efficiencies in HVAC equipment. At the next meeting, the information was presented but was eliminated by the Energy Code Subcommittee in favor of improving the building envelope plus lighting.

Although we did not propose efficiencies on mechanical equipment, we did model other standards that increase efficiency in regards to mechanical equipment operation. First of all, the project team recommended that all air source heat pumps have heat strip control. Like the IECC 2009, it was also recommended that water heating pipes be insulated. Finally, a requirement was recommended that all new homes be built with at least one programmable thermostat.

Air and Duct Leakage Testing

The NC 2009 does not have an air leakage testing option or requirement. However, the code does have a fairly detailed air sealing checklist. The IECC 2009 provided an air leakage testing option using a blower door -- a maximum of 7 air changes per hour at 50 Pascals of depressurization (ACH50). The NC 2009 code does not require duct testing; however, the IECC 2009 requires that ducts are tested with maximum duct leakage to the exterior, in CFM25, equaling 6% of the floor area.

The project team proposed two options for the builder for air leakage compliance. The first option is to follow a detailed checklist of air sealing that would be checked by the building code inspector. The second option allows conducting a blower door test with maximum leakage rate of 4 ACH50, as field experience shows that many homes easily achieve this level of air tightness with moderate air sealing activity.

For duct testing, the code would require a duct test with a maximum leakage rate, in CFM25, of 4% of the floor area. Once again, field tests conducted over several decades reveal this level of duct sealing to be not only achievable, but highly desirable.

Additional Provisions

The project team proposed the installation of energy efficient lighting – specifically requiring that 75% of all lamps in new homes use higher efficiency technologies, such as compact fluorescent (CFL) and light-emitting diode (LED) light bulbs. The payback period for high efficient lighting is typically less than one year.

Working with the residential and mechanical code subcommittees, a minimum ventilation standard was proposed in all new homes. If a fireplace is installed in a home, the project team agreed with the IECC 2009 and recommended that fire places have gasketed doors and use outside air for combustion. The project team also considered proposing the use of a radiant barrier with R-30 insulation, but when modeled, R-38 insulation provided greater energy savings. The committee settled on proposing R-42 for ceiling insulation without requiring a raised heel truss, but *is currently considering a revision to require R-38 statewide for ceiling insulation. The reduced attic insulation levels would cause a small decrease in the energy savings and the additional cost of the home, but would not significantly affect the economic analysis which follows.*

Energy Savings and Economic Analysis

Cost Estimating

The project team contacted contractors and suppliers throughout the state of North Carolina to estimate the cost of the code provisions. Most of the contractors and suppliers were from metropolitan areas, such as Raleigh and Charlotte, but others were from smaller cities like Jacksonville and Hickory. Chris Mathis, a member of the project team, is one of the founding members of the National Fenestration Rating Council (NFRC), and he communicated with multiple window professionals to retrieve accurate prices for the proposed upgrades to the windows. The project team also worked with Stock Building Supply Company, to double check on the prices of the windows. RS Means software estimating program was also used for cost estimating. For each measure, a high estimate and low estimate was established.

After receiving prices from all of the different sources, the project team presented the information to the Energy Subcommittee. There were questions concerning the prices, so Mike DeWein, with the Alliance to Save Energy, was contacted to check our cost estimates. Overall, he found the prices to be accurate.

Environmental Analysis

For the environmental analysis portion of the report, the project team estimated at the reduction in CO_2 emissions (in tons) due to the energy efficiency measures. The team also studied the possibility that the energy efficiency measures could reduce the needs for future electricity generation in the state.

Mortgage Analysis

In order to show a positive gain for the consumer, the project team studied mortgage prices and price per square foot for construction. We found the median price per square foot for a home in the south to be $77.00, a very conservative number for many developments in North Carolina. This estimate came from research conducted by the National Association of Homebuilders.

2500 Square Foot Home, in Zone Four, with a Slab Foundation using 5.8% Mortgage Rate	
Energy Efficient Enhancements $	$1,500
Mortgage w/ enhancements	$187,400
Monthly Payment	$1,109
Increase in Monthly Payment w/ enhancements	$8.50
Annual Energy Savings	$430
Money Saved Annually with Energy Savings	$320

The project team evaluated 36 homes with a variety of efficiency fixtures. A 5.8% interest rate with a thirty-year loan period was used to calculate monthly and annual mortgage payments. This study was conducted throughout 2009, and mortgage rates during this time were anything but constant, so sensitivity analysis examined the impact of rates varying from 4.8% and 6.8%.

For each type of home and package of measures, the project team found the monthly payment for homes with and without the energy efficiency enhancements. The team members also analyzed the data from the energy modeling computer runs and found the estimated annual energy savings for the more code compliant homes. After completing this calculation multiple times on all the homes in all the climate zones, the average payback period for the energy efficient enhancements averaged at about five years.

For the study, energy prices were not increased over time but were kept at the same rate as 2009 prices. The efficiency, monthly savings, cost, and payback were all calculated for each individual measure. Savings from using smaller HVAC equipment were also not included in the economic calculations.

Energy Code Related Meetings

Throughout the spring and summer and fall of 2009, the project team had conference calls with the Energy Code Task Force. The Task Force worked together to discuss different issues concerning the project and to ensure that the proper code language would be included in the new code. The sessions with the Task Force were utilized to increase our knowledge of the expectations of the Subcommittee and help prepare us for our presentations.

We also made five presentations to the Energy Code Subcommittee concerning the project and the proposal. The presentations included handouts for the committee members and always generated questions for the project team.

Many of the members of the Building Codes Council are on the Energy Code Subcommittee. For example, the chair of the Building Codes Council is Dan Tingen, and he is also a member of the Energy Code Subcommittee. Throughout the process, members of the project team kept in constant contact with Dan Tingen, chair of the Building Codes Council, and Robert Privott, Director of Codes and Construction at the North Carolina Home Builders Association, which was beneficial for our progress. Information was also presented to the Residential Codes Subcommittee, and members of the Project Team attended the June Building Codes Council meeting introduce the project to key members of the Building Codes Council.

Summary of Results

The proposed measures that the project team studied had positive results. The following chart shows the range of payback periods for the different measures. As a general indicator, assuming that future electricity and fuel prices increase at 1.5% per year payback periods translate into annual % returns as follows:

- 5-year payback provides an annual rate of return on investment of over 21% per year
- 10-year payback provides an annual return on investment of almost 11% per year.
- 14-year payback provides an annual return on investment of over 7% per year.

From Zone Four Base	Heating	Cooling	Lighting	Total	% of Annual Energy Saved	% of Annual Energy Bll Saved	Total MMBTU Cost	$ Savings Per Year	Original Cost	Low Upgrade Cost	Low Payback	High Cost	High Payback
BTUs	73.1	12.4	9.0	94.5			$ 1,473.88						
Envelope													
R 10 Slab Insulation													
R 18 with 2x6 24" OC	64.5	12.2	9.0	85.7	9%	8%	$ 1,358.06	$ 115.82	$ 3,203.50	$ 218.87	1.9	$ 1,091.52	9.4
R-13+5 OC, OSB, 1" foam, 2x4 16"	62.1	12.1	9.0	83.2	12%	10%	$ 1,324.64	$ 149.24	$ 3,203.50	$ 980.66	6.6	$ 2,026.70	13.6
R 13 + 5 with let in bracing 2x4 16" OC	62.1	12.1	9.0	83.2	12%	10%	$ 1,324.64	$ 149.24	$ 3,203.50	$ 1,071.62	7.2	$ 2,140.40	14.3
foam corners, 2x4 16" OC	62.1	12.1	9.0	83.2	12%	10%	$ 1,324.64	$ 149.24	$ 3,203.50	$ 616.82	4.1	$ 1,571.90	10.5
R 15+2.5, OSB corners, 2x4 16 OC	64.8	12.2	9.0	86.0	9%	8%	$ 1,361.93	$ 111.96	$ 3,203.50	$ 343.94	3.1	$ 1,230.80	11.0
R-13+2.5, OSB Corners, 2x4 16" OC	66.4	12.2	9.0	87.6	7%	6%	$ 1,382.55	$ 91.33	$ 3,203.50	$ 298.46	3.3	$ 1,173.95	12.9
Windows	72.7	10.5	9.0	92.2	2%	4%	$ 1,421.53	$ 52.36	$ 5,585.49	$ 343.30	6.6	$ 377.63	7.2
Air Leakage	67	12.3	9.0	88.3	7%	6%	$ 1,392.77	$ 81.11	$ -	$ 175.00	2.2	$ 250.00	3.1
Duct Leakage	68.8	11.6	9.0	89.4	5%	5%	$ 1,398.58	$ 75.30	$ -	$ 175.00	2.3	$ 250.00	3.3
Air and Duct Leakage	62.6	11.6	9.0	83.2	12%	11%	$ 1,318.66	$ 155.22	$ -	$ 350.00	2.3	$ 500.00	3.2
Lighting 35 bulbs	75.4	11.9	4.9	92.2	2%	6%	$ 1,389.26	$ 84.63	$ 15.75	$ 63.00	0.7	$ 110.09	1.3

As shown in table below, the enhanced measures that were modeled met the 30% goal. The greatest energy savings were achieved for the 1,800 square foot home constructed on a slab in Climate Zone 3.

Payback Period and Annual Net Gain

The average payback period for the combined measures ranged from 2.2 to 7.6 years, which is equivalent to a 14% to 47% annual rate of return on investment – an attractive range for future energy savings compared to initial costs of installation.

Average Payback Period for All Zones						
	1,800 sq ft		2,500 sq ft		3,500 sq ft	
	Slab	Crawl	Slab	Crawl	Slab	Crawl
Low	3.9	3.8	2.8	2.5	2.5	2.2
High	6.0	7.6	5.2	5.5	5.0	4.7

The annual net savings table included below details the annual financial return that the homeowner receives from the measures in the energy code that was proposed. In all cases, the measures provide a positive cash flow.

Weighted Average % Reduction For All Zones & For Both Foundation Types					
1,800 sq ft		2,500 sq ft		3,500 sq ft	
Slab	Crawl	Slab	Crawl	Slab	Crawl
37%	31%	34%	34%	34%	33%

Over the 3-year code cycle from 2012 to 2015, 120,000 to 160,000 homes will be constructed in North Carolina. The net annual energy savings to the state will total $50 to 75 million dollars per year. In addition, the investment in efficiency measures will provide

Average Net Annual Savings for all Climate Zones					
1,800 sq ft		2,500 sq ft		3,500 sq ft	
Slab	Crawl	Slab	Crawl	Slab	Crawl
$ 260	$ 150	$ 420	$ 370	$ 510	$ 520

jobs for emerging companies, such as energy service firms, insulation companies, and HVAC contractors. The total additional investment would be in the range of $300 to $450 million, which would result in an additional 5,000 to 10,000 direct job-years over the next three years.