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Introducer: Hello, everyone, and welcome to our Building Energy Codes broadcast presented by the Department of Energy Building Energy Codes program. I'm Pam Cole with Pacific Northwest National Laboratory, and we have a webinar every other month at the same time. So it's the second week – Thursday, same time, 10:00 a.m. Pacific Standard Time. So the course description for today – we will be talking about burying ducts, first looking at prescriptive requirements that are now in the 2018 International Energy Conversation Code. This presentation will look at how the buried ducts that don't have a code, some tips, and then we'll go through to demonstrate how you would go about, you know, following the code measures if this is something that you'd like to do to bring into your construction process. Next.

So some learning objectives and what we'd like to make sure that you take away today are – is getting a brief overview of the research that's been done in ductworks and going into conditioned space and then unconditioned space.

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And a summary of the code changes are – if you're not familiar with the code cycle, you might want to go out and take a look at that at ICC's website. Also, a description of how builders in practice today can change as far as looking at practices so a builder might want to modify those and maybe looking at doing buried ducts and create a build for that and an overview what are the energy and cost benefits of using this alternative method or this alternative approach to putting ducts in the attic. And then lastly the synopsis of relevant field research, providing a look at how this can be effectively done and how safely it can be done in all climate zones, even in a hot and humid climate.

So who I'd like to introduce to you today is Craig Drumheller. And he is the director of the construction codes and standards for the National Association of Homebuilders. We have been involved with this group for quite some time, and I don't have to say that

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congratulations on getting these code changes in place for the 2018, put a lot of effort into it, and so he's gonna provide you what happened and the history of how we got to where we are and how Building America research got us here. So, Craig, go ahead.

Craig Drumheller: Okay, thank you, Pam. About two years ago the subject of buried ducts came up in an NAHB meeting to discuss the prospective code changes for the upcoming cycle, which resulted in the 2018 code. And I was surprised at the interest level of the builders, and I even had personal experience and back in my research days had been involved in buried ducts and some of the concerns and advantages of them. And I was – kind of took the lead, but with a lot of help from people who had done previous research, from industry – insulation industry, from –

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builders and HVAC contractors, and really got a good team together. So I can't take full credit for this, but I was involved with it from the beginning and was quite pleased with the life that it's taken on and the level of interest in this particular subject.

So what are buried ducts? You know, if you listen carefully to the words you might think of ducts buried under a slab, you know, in the ground. That's not what it is. And if you don't listen carefully you might hear something like buried ducks. So be careful with your annunciation when you refer to buried ducts, and that's not what it is. But buried ducts are ducts buried within attic installation of vented attics. So this kind of shows how – you know, what we really mean by buried ducts. So the ducts are in some respects outside of conditioned space, but –

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in other respects within the conditioned space, and that's what we're gonna be talking about today.

So the advantages of buried ducts – first and foremost is it saves energy versus ducts that are exposed in the attic. And typically it's a lower-cost solution to bringing ducts fully into conditioned spaces, depending on what the configuration of the house is. Single-story, flat-bottomed grade is very, very difficult to get the ducts in conditioned space, and this is a very practical solution for those particular applications. It can be easily implemented; it doesn't require high-tech solutions. And you know, it's something that a builder can go out and start doing today if their code official allows it.

So buried ducts, you know, versus attics or exposed ducts in the attic –

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traditionally thermal losses are somewhere in the 10 to 45 percent range. It's probably lower than that if you're gonna start talking about today's codes where building tightness or duct tightness requirements are somewhere in the 4 cfm per 100 square foot level, so you know, we refer to that as a 4 percent leakage rate. And in some of the thermal losses – if you go back R4 ducts, not all that long ago, you have considerable thermal losses. When you go up to R8 ducts obviously you cut that in half. But when you bury them, you can almost get a threefold reduction in the thermal losses. So there is significant benefits to be seen with the buried ducts.

Interior – bringing the ducts inside conditioned space. Here are four, five examples of how ducts can be brought within the thermal envelope. I've got a couple slides coming up here that kind of go a little bit more into detail and the advantages and disadvantages of these approaches.

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So for example, ducts in an unvented attic – you know, there's some – I'm sure you all are getting some quick first impressions of that's a lot of spray foam. It does give you some design flexibility with your HVAC system, that you can basically put it anywhere in the attic and you shouldn't have any problems in conditioned space because of the location of the thermal envelope. Very expensive and may increase the overall enclosure loads, because rather than having just the attic floor be that area being the thermal boundary, now you've created a thermal boundary, lifted it up, and have more surface area to your building envelope, which could increase the enclosure load.

Another solution is a duct where you drop the soffit from the traditional ceiling and requires some – in a lot of cases –

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architectural integration that doesn't really affect the feel within the house. If you look over on the right side where they're installing this – tray properly to try to get the ducts in conditioned space, you can see that integrating or coordinating the trays can be very difficult. Typically if you do it wrong you would have a framer and then you'd have drywall – or framer, HVAC contractors, and then the drywall, and then you're done. With this approach you've got the framer, drywall, framer, HVAC contractor, and then you've got drywall again. So it's really not a solution that has really taken hold in the field.

Another approach – and this is really limited to integrated ducts within the floor trusses. You have to have deep open trusses, probably 14 inches. 12 inches may work in some circumstances.

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But this really only works if you have an interstitial space between floors, which would be a one-story with a conditioned basement or a two-story potentially on slab. So there are limitations, but it is another prospective solution.

Ducts in a modified truss, essentially modifying the truss to try to keep the duct truly within the thermal boundary and within the continuous air barrier, but again you have the truss chord – or the coordination of the trades, having to do the ceiling, you know, not using drywall or potentially using drywall, and doing things out of order. And again something that's a solution that's out there, but it really hasn't gotten a lot of traction.

So concerns about buried ducts – so one of the problems – and it is a potential problem, especially in humid clients, is –

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condensation on the ducts. And we've tried to address that. The research has shown when it occurs, where it occurs, and hopefully we've taken care of that with these new changes in the code. Another is displaced attic insulation at least in theory resulting in reduced efficiency. Research has shown that that is not the case. And a new concern with the ducts that are buried – research as shown that the temperature – the air conditioning delivery temperature, of course, if this is really a summertime air conditioning issue – the delivery temperature could be seven degrees cooler than previously if the ducts are outside of – enclosed in the attic. We could have a – we'll say a delivery temperature of somewhere on the order of 65 degrees, and now it could potentially be down in the 58 degree range. So a significant reduction in the temperature –

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also increases the potential for condensation.

So the buried ducts research has been doing on – Building America has really been a strong supporter of the buried duct concept for over 15 years. Steven Winter Associates has really taken the lead and was an early researcher on this. They have some research really going back into the late '90s. But the Building America program really picked it up in early 2000, 2002, somewhere in that range, and has done a number of papers. They've come up with a variety of solutions including encapsulated ducts and recommended areas where it works and doesn't work and different R values. So the really have done a tremendous amount of research. Home Innovation Research Labs, formerly known as the NAHB Research Center where I used to work, recently did a paper back in 2016. And it showed in a humid climate –

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that even an R-8 duct should be able to work without – they did it without any evidence of condensation. So there really is a safety factor built in in some of the code changes that were incorporated. And also Florida Solar Energy Center has also done some research under the Building America name in the past 15 years.

So here's an example of how the insulating of the ducts when they're buried, having this increased R value reduces the condensation potential. So this is at the boot, the surface boot, and it shows the peak RH, the peak relative humidity – if you look over on the right vertical bar, that's a relative humidity of about 90 percent for this particular application. And that's not really in the –

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danger zone, but it's getting close. Just because you're having condensation isn't in itself a real problem; it's the extended periods of condensation is really where you start having a problem, where you start seeing things like staining and then potentially mold growing after that. But this particular application at least, it shows that it's still in a safe zone. But when they applied insulation on the top, when they encapsulated the duct, this is basically – this was the same system and a different day, but relatively similar attic temperatures and relatively similar attic dew points. That same duct, the peak relative humidity is somewhere in the 70 percent range, and even earlier in the day where the potential to drive off the moisture later on if there were to be a problem. So it shows that insulating the ducts actually does make a big difference – or I should say additional insulation on the ducts makes a big –

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difference as far as reduced moisture potential.

So as I also pointed out that this reduced delivery temperature – and again this is in the air conditioning mode, not the heating mode. So the reduced delivery temperature, which is actually a good thing, and the seven degree reduction with the buried ducts clearly saves energy over exposed ducts, but it also increases the opportunity for condensation, most notably at the boot near the supply register. And so I'm using the slide on the – the picture on the right I think helps illustrate where you would see a much colder temperature at the duct boot, where you have the potential for condensation. So potential solutions for that would be having an insulated boot or putting closed-cell spray form over –

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the top of it. So there are solutions to these problems, but just wanted to be aware that we are changing some of the dynamics and it may need some solutions to it. But this is really much, much more of a concern in the southeast than it is anywhere else in the country.

So why the need for a code change? Some jurisdictions do not allow builders to bury ducts. They have concerns about condensation and concerns about reduced efficiency. A little embarrassed, but the slide on the right is actually a slide – is a picture in my attic, where the jurisdiction that I live in requires them to take the duct system and put it up as far as they possibly can in the attic. And it's just – when you think about it from a building science perspective, when you think about it from an energy efficiency perspective, you are taking the – in the wintertime – or the summertime the coldest air in the entire house and you're putting it –

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into the absolute hottest place in the entire house. And even the hottest part of the hottest place in the entire house, where the temperatures can be up to 160, 170, 180 degrees, and then the temperature of the conditioned air going through the ductwork is somewhere on the order of let's say 50 to 60 degrees. So a very high delta T, you know, why don't we lower that, put it into the attic insulation and provide additional thermal benefit? And you can also see there when you have the ducts – the takeoff on the duct with a flex duct that over time other things happen to it. So if you have it flat with the ground, flat with the back side of the attic insulation, you're not gonna have these gravity effects on it that you would in an elevated location.

So the concern was that there was no guidance in the code on how to address condensation –

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and a concern about the reduced efficiency. And so the idea was why don't we incorporate this to explicitly allow ducts to be buried in attics and provide criteria that – we got a bunch of experts in the room to come to a consensus on how to best do that. So in addition to that, not only when you're burying the ducts, are you getting the benefit of the reduced temperature? But you're also – with the change in the energy code to allow builders to receive credit towards compliance because it is a more efficient solution than ducts exposed in the attic. And also there was an alternate proposal or an additional proposal that would show equivalence to a duct being in conditioned space.

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So it consisted of three different proposals as I indicated, one that said, yes, you can allow buried ducts along with criteria, second to get performance credit for buried ducts, and this was based on the research that was performed, and the ultimate criteria for ducts in conditioned space. And these are the actual headers of the proposal that were submitted for the 2016 code cycle that ended up being the 2018 code.

So ducts buried under insulation – it's a viable practice. So the ducts are placed basically on the back side or the top side of the ceiling drywall, over the bottom truss chords. You know, say for the transfers, the trunk line, and then typically the flex ducts or the takeoffs – it could be rigid ducts as well – the takeoffs would be on the back side of the drywall and going to the supply registers, which are typically –

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towards the exterior walls, although there are some shorter compressed duct runs as a solution. This would work with both of those, whether it's a short duct run or a longer duct run. It would be applicable to both. So the reduced thermal losses from ducts that are located in vented attics, and it considered condensation in humid climates.

So prior code additions didn't specifically disallow buried ducts, but it also didn't specify obviously conditions of performance and compliance. So the 2018 code change proposal recognized the buried ducts, specifying the insulated duct R-value by climate zone and addressed moisture concerns, the minimum attic insulation around the ducts which addressed energy performance –

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and Performance Path energy compliance which specifies parameters to be entered in the software when you're doing prescriptive modeling.

So the code requirements for ducts buried within ceiling insulation – first you have to have R-8. Right now R-8 is the prescriptive requirement, but if you're doing a Performance Path you can actually reduce it down to R-6. So if you're gonna bury the ducts for these considerations, you must have R-8 and there is no – you can't back off to R-6 and make it up somewhere else because of some of the concerns with condensation. And R-13 rather than R-8 would apply in climate zones 1A, 2A, and 3A. And the definition of the duct insulation that, you know – as opposed to the attic insulation is – if you look at the three duct examples –

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on the right-hand side, you might say, well, what's the distinction between the duct and the attic insulation? And that would be a vapor retarder. So that is really the defining point between where the duct insulation ends and where the attic insulation begins. And if you have encapsulated the duct, for example, with closed-cell polyurethane foam, the duct insulation is extended right to the surface of that closed-cell foam because of the low permeance of foam and also the jacket on the flex duct also are low perm and – for the purposes of keeping moisture from coming into – from the outside coming into the duct and reaching the cold surface of the duct, that would be the extent of the duct insulation as well.

So – and the ceiling insulation, just –

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to make sure that you're not displacing all the ceiling insulation with the ducts, there's a requirement that says above and below the duct should total R-19, not including the duct R value. And the three examples there are the ducts completely – the R-19 is completely below the duct or some sort of mixture between below and above the duct totaling R-19, or R-19 at a minimum, over the top of the duct. So if you look at – you're considering an R-8 flex duct, you have R-8 on the bottom portion of the flex duct and R-8 on the top, and then R-19 on top of that, you're really pretty much accomplished well over R-30, closer to R-38, even where it's been in theory displaced due to the ducts being there.

So for those of you who aren't intimately familiar with –

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the climate zone map that's part of the IECC, both residential and commercial – but kind of a side note, for 90.1 this is no longer the climate zone map for ASHRAE 90.1. But for this purpose climate zones 1A, 2A, and 3A, which is within that – the red box, if you see at the very top you have the three different moisture regions. A is basically east coast, Midwest, dry would be for the most part the mountains, mountainous and desert climate zones, and the marine would be along the Pacific coast. So this is an issue that's related to moist – moisture regions primarily in climate zones 1, 2, and 3, which incidentally is where the vast majority of – or at least the majority of the building in the United States is going on at this point. And so there –

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the ducts, because of the moisture and the condensation concerns, R-13 or greater for the duct insulation, and everywhere else in the country, including Hawaii, would be an R-8 or greater insulation for the ducts.

So how do you achieve an R-13 duct? For the most part it's not commercially available, although then you could take a – just a bare metal duct and wrap it with R-13 insulation, you know, R-13 blanket insulation you wrap with, just like they wrap it with R-5.6 or R-8 right now with the metal ducts. Or like Steven Winter had frequently been using in their research had been the encapsulated duct. So they would take a typical duct and encapsulate it with one-inch or one-and-a-half inches of closed-cell –

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spray polyurethane foam. As you can see it's a little on the messy side but if done properly it's absolutely a great solution. And in the interim, before it becomes commercially available, the research that Home Innovation had done that's trying to show the performance of a higher R-value duct, when they were using flex ducts they did concentric R-8 ducts. I believe they were built R-8. So you could do an R-8 or an R-6 and you're much – you're right on the cusp of R-14 or over R-13, so you would beat the requirement with that type of solution. We've spoken to some of the flex duct suppliers and they say they're ready to go if there's a demand. So they're willing to participate in this if –

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there's people asking for it.

So here is the actual – with permission from IECC the actual code change proposal that explicitly allows ducts to be buried within the attic insulation. And these are the three components that I had just mentioned that – you know, no less than an R-8 value, the R-19 is the minimum above and/or below the duct, climate zones 1A, 2A, and 3A must be an R-13. And the one exception here is that the last three feet of the duct don't require to comply with these requirements, and the reason behind that, as you can imagine, when we were putting the code change proposals together we were concerned that we didn't want to go overkill and – but we also didn't want to –

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so we didn't want to stop builders from doing that they were already successfully doing and make it more difficult for them, especially when we're talking about the R-13 ducts. And so if they're coming in we'll say from an elevated position in through the insulation, it could potentially be interpreted that while that last couple feet is really buried within the insulation, and – within the ceiling insulation. So we wanted to make it clear that this exception it's not required that you had to have an R-13 duct for that last three feet.

So the second proposal was saying if you deeply bury the ducts within the attic insulation, then you can get credit for it. And when I say credit for it, this would be a Performance Path credit. So ducts or portions of the duct installed as deeply buried can claim this R-25 –

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R value. And when I say may claim – so when you're doing a Performance Path calculation and you enter the duct, they ask you where the duct's located. Are they in conditioned space? Are they in the crawl space? Are they in the attic? Are they buried in the attic? And I would suggest that when – if you're gonna do this type of performance modeling for code compliance with the Performance Path, not the ERI but the Performance Path, that you – they consider it exposed duct at an R value of 25. And this is something that can be evaluated on – let's say you have 100 linear feet of ducts in the attic, and 50 – half of it is buried and half of it is not buried. You can actually parse that out when you're doing data entry to distinguish between –

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deeply buried and not deeply buried ducts and get the R-25 for the deeply buried ducts, and if they're exposed, then you just put the R-8 or the R-6 or whatever the insulation level is on those particular ducts.

As far as the duct location, it has to be within five and a half inches of the ceiling drywall, and a couple reasons for that. One is to be able to go above two by six studs so you could drape it across the studs, or if you're having a takeoff on a duct that's over a two by four bottom chord, that you can be a couple inches above that as far as your takeoff on that – on the main trunk line and still meet that five and a half inch maximum. And also the ceiling insulation and the – maybe the language wasn't perfectly crafted here, but the R-30 –

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surrounding the duct is really implied to be the duct – the insulation – the attic insulation, not the horizontal R-30, you know, to the left and the right of the duct. I don't perceive that as being a problem, but at this point it could potentially be interpreted either way. But I don't see either one being a problem.

And so here's the actual language for this RE110, which is the designation for the proposal on the effective R-value of deeply buried ducts, again showing the five and a half inches, and make sure that the R-value is 30 around it and not less than three and a half inches below the top of the insulation. And shall be considered as having an effective duct insulation R-value of R-25.

So the third component was ducts –

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being located in conditioned space. And so there's four requirements that were part of that proposal, and one is that it needs to meet these requirements, as I go back up a slide, for the – I'm sorry, the – these requirements, so the ducts being buried within ceiling insulation. So first of all, it has to meet all those requirements. And then the air handlers must be within conditioned space, so you can't have the air handler in the attic.

And third, the duct leakage – now this is a very aggressive number, the post-construction – it's a post-construction test because it will be leakage to the outside of 1.5 cfm per 100 square feet of conditioned floor area. So the requirements right now for ducts that are outside of conditioned space is 4 cfm per 100 square feet, and that's a fairly aggressive number to begin with. And now to turn that into 1.5 cfm is –

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quite aggressive and I would only suggest this for builders that are very confident that they can do this and they can do this repeatedly. So there's some concern there, but it's not unachievable. It's just something that should be taken into consideration before you do it the first time. And this number is actually even more stringent than the DOE's Zero Energy Ready Home requirement, which requires ducts to be in conditioned space, but it has essentially an exception if you're at 3 cfm per 100 square feet and you're under three and a half inches of insulation. Well, here it's 1.5 cfm per 100 square feet, and point number four here says it basically has to be under the requisite amount of ceiling insulation that's being used, so that – you know, being proposed for that particular house. So if –

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it's, for example, R-38 is the requirement, then you have an R-8 duct, you need R-30 on top of that so you meet that R-38 requirement. So it's – you need to have basically the full amount of insulation and it needs to be a super-tight duct. So that's kind of the – the summary and the duct need to be in – or the air handler must be located in that conditioned space.

So here's the actual language for that, pretty much mimics with what I just indicated.

So implementing buried ducts with previous code editions – the 2018 IECC was just published and – published in I believe early September. And at this point in time no jurisdictions are on that code; they're all on previous versions of them. So buried ducts can still be implemented using provision –

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for alternative compliance. It's – alternate means and – or alternate materials, design, and methods, which is IRC's section R104.11. And most code officials are pretty friendly to accepting options that are included in newer editions of the code, so I wouldn't perceive that as being a problem, if you want to comply with the 2018 IECC.

So when you're doing Performance Path or ERI compliance, the 2018 code has reduced energy usage options that can be claimed towards compliance when using both the Performance Path and the Energy Rating Index. So the types of installations include deeply buried R-8 ducts where you can use the R-25, and you can consider the ducts in conditioned space as I indicated –

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if the area was in the conditioned space. You need the 1.5 cfm and there's proper-mounted insulation above that duct system.

I did some energy modeling and came up with some interesting results using two different commonly-used pieces of compliance software that are out there. I won't name them; it's not important. But – so if we were to start with a house that just barely complied to the code, this particular house is I think around 2,000 square feet, located in the Dallas/Fort Worth area, slab on grade, just meeting the requirements of the 2018 IECC. So if you look at A and B on the far right for IECC Performance Path, so in theory these two houses just barely comply with the Performance Path. They just make it – zero percent. It's right on the margin.

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And to the left are the two corresponding ERI scores for that particular house. So as you can imagine, now if you're gonna take R-8 exposed duct in the attic with a four percent leakage that just meets the code and you bury it, now you can claim R-25 duct insulation. And pretty much across the board 2.2 ERI in both software A and software B, about a two percent meeting minimum IECC requirements with software A, three percent with software B. And that was really is the distinction there. So it shows that there is a benefit, just strictly burying the ducts gave you roughly a two percent or – improvement towards code compliance. And also as you can imagine, as they get tighter – 0.3 percent. 0.2 percent, 0.1 percent, and zero percent –

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you get a nice smooth, you know, reduction in your ERI or increase in your IECC Performance Path above the minimum requirement.

So what's interesting was – and this is based on the way the language is specifically written, and I had discussions with both software manufacturers and they understand the concerns or the inequity of this. But if you take that same house that just barely passed – the attic exposed, the very first one, zero percent, right on the margin – and you bring those ducts from outside conditioned space to inside conditioned space, using the IECC Performance Path they all fail, anywhere from whether it's tested to zero leakage or you took the testing exemption. With the Performance Path they fail, and in the case –

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of the texting exemption with the software A, it misses by six percent, so not a trivial amount.

So where I'm going with this is if you're gonna use the Performance Path, you might not want to consider those ducts in conditioned space. You might want to model them as if they're deeply buried ducts and you'll probably come out ahead. But if you're using the Energy Rating Index, that has a fixed baseline. So the baseline defines and it holds true for all simulations. The way the Performance Path – it does not define a location of the duct; therefore if you move the duct – if the duct is outside it's compared to an outside duct. If you move it inside it's compared to an inside duct. And there are some nuances in there that really kind of throw this off. And it shows up in this particular modeling scenario, and something that –

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I've already discussed with DOE and I think we need to continue that discussion and hopefully we can have that resolved. Unfortunately it's gonna take three years to resolve it.

And the footnote here – REScheck does not model duct performance, so it's not – it wouldn't be applicable under the – doing this as a REScheck, even in the performance portion of REScheck does not allow modeling of ducts to this level.

So in conclusion, our – the 2018 IECC has changes that will specifically allow buried ducts where it was ambiguous before, along with requirements for buried ducts. Code changes also give energy credit for deeply buried ducts that result in about three percent or two ERI points. And properly installed ducts can be considered in conditioned space, which works in the ERI path; however, caution should be used –

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when considering this option in the Performance Path. So it could be beneficial to consider the ducts outside of conditioned space. And also a need to consider – the delivery temperature will be lower and with an increased condensation potential at the register boot. So I'm not saying it's gonna happen. I'm saying that if you're right on the margin to begin with that you're beginning to push your luck.