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Pam Cole: Welcome, everyone. I'm Pam Cole with the Pacific Northwest National Laboratory, and I'd like to welcome you today to the Energy Codes Commentator webinar: Achieving a More Meaningful Assessment of Commercial Building Code Compliance. And we hold these webinars the second Thursday of every other month at the same time. So, keep a watch out on the building energy codes training page as topics get added. So, the next webinar will be in December.

If you have any topic suggestions you'd like us to consider, please e-mail them to us, and you can use the same e-mail that you received for your webinar reminder for the webinar messages that you received. So, what this webinar's about is it's going to describe two recent studies that have attempted to develop a deeper more meaningful assessment of commercial building code compliance.

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The first study was conducted by PNNL trying to answer the question, how much energy cost savings can be achieved through better compliance, and the second study that will be discussed today was done by Ecotope and argues the evaluating codes should be directed at perennial need to understand and approve the construction of new buildings.

So, as far as learning objectives, at the end of this course or this webinar, participants what they should be able to take away is why are commercial energy code compliance assessments more challenging than residential assessments. And what are more meaningful assessments of energy code compliance than simple pass or fail metrics? How code evaluations can support interdependent efforts such as code design enforcement training and utility programs. And then the last objective would be, what is the relationship between code compliance and post-occupancy energy use?

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So, I would like to introduce my speakers to you today, and we really appreciate them taking the time out to share this information with us. We have Mike Rosenberg from PNNL, and Poppy Storm with Ecotope. And they will be discussing these two studies, and I'd like, Mike, go ahead and take it away and begin.

Michael Rosenberg: Okay. Thank you very much, Pam. First, a little bit of background before we get into the study itself. So, why is commercial compliance different than residential? It's a lot more difficult, and there's a number of reasons for that. First, it's just the size of the code. The residential code the IECC energy efficiency Chapter's 13 pages long. The IECC commercial chapter is 62 pages long. There's a lot more measures to verifying compliance.

You know, our residential studies that we're doing, compliance studies, we're looking at 11 different measures. In the commercial studies it's about 100. And then the code changes at a more rapid pace in commercial than residential.

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Since 2004 there's been 191 changes to the residential code, the IECC, 263 to ASHRAE standard 90.1, and then those changes themselves are at a different level of complexity. So, building controls, things like temperature resets, pump controls, daylighting controls, fan controls, there's only four of those that have been introduced into the IECC, the residential code since 2004, 70 of them in the commercial code.

And then the building types that you're dealing with. The residential code deals with single family and low-rise multi-family. The commercial code deals with high-rise multi-family, warehouse, office and schools, labs, assembly buildings, sports arenas, hospitals, medical office buildings, retail, hotels, industrial. It just goes on and on.

And then finally the HVAC equipment, in a residential code you're mostly dealing with furnaces, heat pumps, air conditioners, maybe electric wall cadets and radiant heaters or radiant floor heating.

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In the commercial you're dealing with all those plus variable air buying systems, built up multi-zone systems, water source heat pumps, ground source heat pumps, fan coil units. You've got cooling towers and pumps and eight different kinds of chillers. You've got boilers, chill beams, just much more complex. This next picture shows what you might see if you go into the mechanical room in a commercial building. So, it's obviously a pretty complex place.

Okay. Previous compliance studies done by DOE focused on checklists and percent compliance. They were basically pass/fail, there was a binary decision made for each requirement, did it pass or didn't it pass? The impact of partial compliance wasn't really considered. So, if you had a building that the lighting power was ten watts over the allowance it failed. If it was 1000 watts over the allowance it failed. There was no distinction made between those two.

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And then the relative importance of different requirements were either ignored or not looked at objectively. So, quantitatively what's the difference between building equipment efficiency that doesn't pass or lighting power that doesn't pass or insulation that doesn't pass? That was really not done in an analytical way.

This is a copy of one of the previous checklists that we used in DOE commercial compliance studies. You could see here each of the requirements, and just you check off, does it comply? Does it not comply? You can't see it, or it doesn't apply to the building. So, that level of information and then maybe some comments.

So, the current project, it was a pilot project, we wanted to not ask the question, does the building comply, but instead ask a different question. How much energy cost savings could be gained through or saved through better compliance with the code, and how do we capture that savings effectively? So, really, how much savings is being left on the table through non-compliance, and how can we capture it with the biggest bang for the buck.

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So, the pilot project took a very simple approach. We looked at one building type, small office buildings with simple HVAC systems in one climate zone, 4C – that's the western quadrant of the Pacific Northwest – and in one code, the 2012 IECC, International Energy Conservation Code. So, before we could actually go out and do audits and assessments, we had to do some up front preliminary analysis.

The first thing we did was we went through the IECC, and we identified all the individual requirements. It turns out that there's 396 different requirements in the 2012 IECC commercial provisions. We went through those, and we eliminated all those that didn't apply to the building type that we were dealing with, the small office building, didn't apply to simple HVAC systems, didn't apply to climate zone 4C, and those that were not responsible directly for energy savings, like administrative requirements.

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Once we did that we had 149 requirements left, and we looked at those requirements, and we grouped them into what we call measures. So, for instance, for occupancy sensors there's basically three requirements in the code. The first says that certain space types, like enclosed offices need to have an occupancy sensor present.

The second says it has to be a manual on, it can't just turn the lights on when somebody walks in. You have to turn the lights on manually, and it automatically turns them off. That's sometimes called a vacancy sensor. And then the third requirement is that all the lights shut off within 30 minutes of the last occupant leaving the room.

So, those three requirements became one occupancy sensor measure. So, we did that with all the 149 requirements and we ended up with 53 measures applicable to our building type and climate zone. Once we identified those measures we first identified what the code condition was, and we also identified two conditions worse than code. We called them below and worst.

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So, for example, roof insulation is a requirement for the U value of roof insulation. If it's got all the – there's a requirement for the U value of roofs. If it's got all the insulation it needs it's 100 percent of the required U value. Less insulation or below code condition was 150 percent, and then the worst condition was no insulation at all.

Thermostat deadband, which is a requirement that says there needs to be an offset between the heating and cooling set points on the thermostat. The code condition is a five degree deadband. Below code condition we identified was two degrees, and then the worst case no deadband at all.

Interior lighting power allowance, it meets the whole building lighting power. That's the code condition. It exceeds it by 50 percent that is the below code condition. And the worst was that it exceeded it by 100 percent. And we did that just for these three for the remaining measures. So, we had conditions for all of them.

Next we needed to assign a lost energy cost savings for each of those conditions for each of those measures.

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So, we did that using energy simulation. PNNL had developed this suite of prototype buildings that we use for analysis. For this analysis we used the small office prototype. We used average national utility rates from EIA, and then once we got the loss savings we normalized it to the appropriate metrics for the measure.

So, for example, if it's roof insulation per square foot of roof insulation. If it was cooling efficiency, per tons of cooling. So, showing here, for example, for the roof, obviously, if it has 100 percent of the required U value, the code condition there's no lost energy cost savings.

Simulation showed us that if was 150 percent of the required U value that was worth 1.5 cents per square foot of roof area. And then if there was no insulation at all in the roof, 53.7 cents was the worst condition. Interior lighting power allowance once again, if it meets the code requirement, low lost savings, if it exceeds the allowance by 50 percent that was worth 15.2 cents per square foot of building per year.

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If it exceeded it by 100 percent, 30.4 cents per square foot of building per year. And we did that for all the measures.

Okay. So, the preliminary analysis is done, now a little bit about the field work. So, one thing this pilot project did not do is develop a recruiting strategy or a sampling procedure. That really wasn't the research question that we were interested in. It was more the question of determining the lost energy cost savings. We hired a contractor to do the actual field auditing. That was Ecotope, Poppy's company.

They used the Dodge database of new construction and used the cold call approach. So, they identified 121 candidate buildings that fit our requirements, newly constructed, small office buildings, simple HVAC systems in climate zone 4C.

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And out of those 121 candidates they were only able to recruit 9 of them. So, 7.4 percent recruiting success rate. So, pretty low. And on average it took ten phone calls to each of those nine buildings to screen, recruit and schedule the visits. It turned out that for this whole process recruiters spent about 135 person hours to get the 9 buildings. So, that's about 14 hours spend in recruiting per building. So, obviously, very, very time intensive and obviously we probably need to explore some other ways of doing this than the cold call approach.

For the field audit procedure the first thing they did was to collect construction documents and review those and then go out to the building itself. And from both those, the document review and the field audit they were able to determine the condition of each of the 63 measures.

Now, they only went to each site once. That has some implications, mostly that you're not going to see everything on one site visit.

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So, for example, if you go right at or after occupancy you're not going to see slab perimeter insulation or wall insulation. So, for those measures that they could not directly visibly observe, they had to infer the condition from the document review, construction document review.

Okay. So, after collecting all that data from the nine buildings, the condition of each measure, the calculation of lost savings. It's really pretty straightforward based on the savings that we assign to the conditions in the preliminary analysis. So, for example, if they went out to a building and there was 900 square feet of roof area in that building, and the value was 150 percent of what's required by code we previously determined that was worth 1.5 cents per square foot, multiplied by the number of square feet.

So, for that building, that condition the roof insulation that did not meet code was worth lost energy cost savings of $13.50 per year for that building.

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So, the entire building lost energy cost savings was simply the sum of all the measures and the sample lost energy cost savings is the sum of all the buildings, of all nine buildings.

So, a summary of the results. So, there were 63 measures. It turned out that 19 of them were not applicable in any of the nine buildings that we visited. For example, there were no basements in the nine building samples. So, the basement, the below grade wall insulation measure was not applicable. There were no skylights, so, skylight U factors and solar heat gain coefficients were not applicable.

Of those that were applicable, 95 percent of them were verifiable. So, either through planner inspection they were able to tell the condition of the measure. Five percent they could not tell at all. And of those that were verifiable, 75 percent comply.

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So, thinking in terms of the old DOE methodology pass/fail, the sample of nine buildings would've scored a 75 percent compliance rate. But as we discussed that's worse in some different results here, and that's what's shown below. So, you can see these are the nine buildings. They were relatively small buildings, 27,000 feet total.

Each of the buildings were showing the annual lost energy cost savings per year, so it ranged from a low of $101.00 per year for this building to a high of $638.00 per year for this building. And then what we also did is we looked at the loss savings from a life cycle cost perspective. So, over the life of the building what the present value of the lost energy cost savings would be.

So, in summary, if all nine buildings would've complied fully with the code, the total savings would've been $3372.00 per year or $46,430.00 over the life of the building. So, that answers the question, what's the lost energy costs savings that could be recovered through better compliance for this nine building sample.

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This was a simplified approach, one thing that we didn't do was consider the interactive effects of different measures having different conditions. So, for example, if you combined windows that are worse than code with an HVAC system that's worse than code you're lost energy cost savings is going to worse than if you have those same windows in an HVAC system that met code. The procedure that I just outlined didn't account for that.

So, we wanted to test that and say, "Okay. How important is that simplification?" So, what we did is we took the average condition for each of the measures that we found out in the buildings and we combined those into one single interactive building model. And then we compared the lost energy cost savings from that interactive model to the sum of the lost energy cost savings from the individual measures.

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And so, you can see here from the interactive simulation the result was $3603.00 lost energy cost savings, and you can compare that with the sum of the individual measures, $3372.00 a difference of $231.00 or 6.8 percent difference. So, a fairly modest difference, probably worth the simplification in our mind.

Okay. Something else that this study did that I don't think has really been done in any of these compliance studies before is we had the auditors track time to verify compliance. So, they tracked the time for individual measures, so how long did it take them to count lights? How long did it take them to assess the roof insulation? But also how much time did it take them to get out to the site, to collect the plans, to go through any kind of security screenings that they needed to do? Those indirect costs.

And then they prorated the indirect costs to the measures, and we were able to identify a verification time for each of the measures.

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So, we're showing here in this table, so we're listing each of the measures and how much time they took. So, for example, to verify mechanical systems commissioning, whether that was done or not. That took a little less than a half hour for all nine buildings. You could see if we look at a high one, interior lighting power allowance. That took four and three-quarter hours to determine the lighting power in all the nine buildings together.

So, in total 61 hours approximately was spent on verifying measures that did have some below code potential savings. So, in other words, the 61 hours is for all measures that did not comply at least in some of the buildings. Forty-one hours was also spend on buildings – on measures that complied in all the buildings. It takes time, obviously, to see that measures comply.

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So, 102 hours for the nine building sample. So that's about 11 hours per building that was spend on this pilot project, and these were pretty simple buildings.

Here I've added a lifecycle cost savings for each of the measures along with the verification hours. So, you can see pretty high the commissioning was a big lost energy cost savings, equipment oversizing was pretty significant, some of the others, damper control, which spaces are unoccupied pretty low. So, if we combine those lost energy cost savings with the verification hours we created a new metric, potential lost savings recovered per hour of verification.

And you can see a pretty big range, mechanical system requirement had the biggest bang for the buck potentially all the way down to the damper control low. Kind of an average for all the applicable measures, –

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we could recover potentially $455.00 over the life of these nine buildings per hour spent on verification. So, this is the biggest bang for the buck question.

So, a little bit about ranking these measures. So, our thoughts are that for all compliance studies in the future it's probably not realistic to verify all the measures. I said we spent about 11 hours on each of the nine buildings, and they're pretty simple buildings. That might not be within the resources that some studies have.

So, we wanted to look at some ways to prioritize the measures and try to make things simpler. For these simple buildings we had 63 measures. If we have a complex building with central plants, chillers, boilers, laboratory, hospital, we could easily double the number of measures. So, you can see it can quickly get out of hand.

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So, to prioritize we looked at two different ways of prioritizing these measures. Focusing on the biggest bang for the buck, the dollars saved per verification hour and then the second way was from the simulation sensitivity analysis that we did up front. The preliminary analysis where we looked at the highest potential lost cost savings of the worst case condition.

So, this chart is just another way of looking at the table that we looked at before, the savings per verification hour. We saw the range of numbers, but seeing it graphically really shows there's a really big difference. Maybe there's no point in looking at some of the ones down here.

Now, one thing to keep in mind, these are results from a nine building sample. We're not making the case that anyone should take these results and then not look at these measures, but this is just to test the procedure. So, in a larger study, much larger than nine buildings, we'll get the same kind of data where maybe we can draw conclusions about which of these measures need to be looked at and which maybe don't depending on the resources available.

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This table shows some interesting results. We took the dollars saved per verification hour and we grouped them into bins of high loss savings per verification hour, medium loss savings, low loss savings, those are measures that were compliant with the code and those measures that didn't apply at all to the code.

And if it turns out that 14 percent of the measures, or nine measures were responsible for 81 percent of the savings. So, that's pretty clear that we did not have to look at most of the measures to get most of the savings in this building sample, and we think that's going to carry out when larger samples are looked at as well.

Okay. The second way that I mentioned, ranking based on the sensitivity analysis, we identified the worst case condition up front and we simulated the lost energy cost savings from that, so we can tell what's the worst possible lost energy cost savings for each of these measures?

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In other words, if it didn't comply at all with the thing you might – the worst cost savings you could have and that's what this chart shows. And also, once again, a very big range. So, you might want to draw a line here, here. I mean, if it's a well-funded study or if it's a true jurisdictional compliance assessment they may want to look at everything. Others may want to look at just some of these.

The good thing about this second methodology is that it can be done up front before you're even out in the field. So, at a future study, so the bang for the buck metric we need to collect a lot more data in order to make some determinations of impact from that. This one can be done up front through simulation and really save some field time in future studies.

Okay. Future implications. What are we going to do with these results? What have we learned going forward? A couple of things – I think the first thing that's important is what we just talked about the prioritizing measures, –

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we want to eliminate the low worst case potential loss savings based on up front simulation analysis and once a lot more data is collected we want to rank these things again and possibly change that – possibly be able to eliminate more measures even.

So, the time it took, 11 hours per building for a simple building and, obviously, that's going to be longer for complex buildings. It just – it's not going to be within the reach of many compliance studies to spend that much time.

The second thing has to do with the recruiting, 135 person hours to recruit nine buildings, 14 hours a building is probably not doable long term. We've got to find a better way. The seven and a half percent success rate with cold calling also not something that probably is going to have long-term success.

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So, the other way that we think has some potential, and we want to test out is trying to piggyback these types of compliance assessments with jurisdictional compliance activities. So, in other words try to connect with the building officials in jurisdictions and become part of the process when they go off the site you go out there with and when they access documents, these compliance studies access documents at the same time.

So, you're not spending time trying to recruit, recruiting is sort of almost a non-issue if this can work out. So that's something we really want to try in the future.

And then finally, the last, I think, lesson learned here is that one visit is not enough to assess all measures. We don't really want to rely on document review to determine the condition of the measures. We really need to see what's going on out in the field if we want to have confidence in the results.

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And that means that one site is not going to work for each building in order to verify all measures. That doesn't mean you have to go out to each site more than once. The residential compliance study is taking a different approach. They go to each home one time, but they only collect the data during that one visit that's visible.

So, if they go after the home is mostly constructed they're not going to see wall insulation. If they go during framing, they're going to see – or right after framing they're going to see wall insulation. So, they just have to go to more homes to collect the number of data points that they're looking for, but they're not getting them all from one house.

Okay. So, further, I mentioned this was a pilot study. DOE is taking the approach that we developed in this pilot study and rolling it out in a much bigger study. They recently awarded $1.7 million to IMT, the Institute of Market Transformation. And they're going to be looking at up to 250 buildings in three states beginning right away –

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and giving feedback and tweaking this process and trying to optimize is so that we can get some good results and more data.

So, that's it. As Pam said, I can address questions at the end, but now I'm going to turn it over to Poppy Storm from Ecotope. Go ahead, Poppy.

Poppy Storm: Thank you.

Michael Rosenberg: It might take a minute to get it over.

Poppy Storm: Yes. I'm just switching my screen. Okay. So, I'm going to talk about a pilot study that Ecotope implemented with the Northwest Energy Efficiency Alliance. So, we designed and tested a methodology to initially look at code compliance assessment, but that quickly turned into a broader code evaluation.

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And in this PowerPoint I'm going to focus mainly on the conceptual framework for this methodology plus some of the results that really illustrate the value of the data and the analysis that are the main outputs of the methodology.

So, I'll start with a little bit of the background and the key drivers for the study. So, as I mentioned, it started out as a code compliance study, and it was a pilot, and it was looking at addressing some of the same issues that Mike just described just the complexity and cost of doing a commercial code compliance study.

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But as we were proceeding through the study design phase a major disconnect emerged between what the Northwest Energy Efficiency Alliance's goals were. They're referred to as NEEA. Their goals were not really aligned with a straight code compliance study where you're getting a straight code compliance determination. So, in spite of the fact that that was the initial plan they really were looking at getting a deeper value and that's why we had to transition the methodology.

NEEA focuses a lot on market transformation. So, they're working holistically on many fronts where they're looking at emerging technology we use, measure development, utility programs and codes.

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And so they are able to expand their understanding of what a code compliance study should be and broaden it to other groups and teams with their organization to add more value for the region.

So, their goals really were to inform code development, to inform training and enforcement efforts. They also were very interested in looking at progress and energy performance in new commercial buildings and hopefully looking at that over time. So, they really wanted to get some actionable results from their investment in this type of study.

And so, that's when our study design really moved into being more of an evaluation approach that moves away from this narrow compliance determination –

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where you're looking at 100 or nearly 100 individual components and having an approach that moves more toward building systems and understanding the impacts of characteristics and the code on actual energy use.

So, in this sense because codes are working within this larger ecosystem of this transition in new construction, codes are seeking to influence code current practice essentially. If we move away from just the strict interpretation of codes and the development of codes. Really ultimately we're trying to see, in many cases, a steep decline in energy in the building stock across the country –

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and in this particular case we're looking at the four states of the northwest. So, codes are seeking to influence current practice and they're doing that in order to reduce energy use over time.

So, the objective of this methodology is to determine how new commercial buildings are actually being built. What level of code compliance is achieved in those buildings and how that compliance influences energy use? And to do this we were really focusing on empirical data and looking at compliance within the context of overall energy use.

So, the compliance was determined by going out to 12 sites in Washington State and collecting detailed characteristics for those buildings.

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And then analyzing the compliance of some of those characteristics by major system type. Looking at envelope, mechanical and lighting. So, this approach allowed for a direct comparison of our compliance findings with the detailed characteristics, the system designs and the actual energy performance of the buildings.

So, current practice and actual energy use are at the heart of this methodology. And the reason why that is a central scene for the study is that its programs, code programs are seeking to influence current practice and reducing energy use over time.

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In current practice and energy use, the actual energy use and characteristics of these buildings should be at the heart of the code evaluation. And to do that we actually need to be looking at whole buildings so we're understanding on a building by building basis, how are the systems designed in this building? What are the key characteristics? What level of compliance are they achieving? And what is the energy use in each of those individual buildings? So that it can be extended statistically across the entire building stock of the state, for example, which is the intention for the future implementation of this methodology.

So, a compliance determination is important but it should in an evaluation, but it really should be supported by detail characteristics–

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so that the building systems that are contributing to the energy use can be understood and used to improve future codes. So, we need to understand how buildings are being built so we can know how to design better buildings, and that's really a precursor to designing better codes. It's all connected to improving the building design and construction so we can reduce the energy use.

And I think this is especially important for mechanical systems. We've made some good progress. I think this is overall for the national codes, but particularly what we're seeing in Washington State and other states in the northwest, we've made pretty good progress on influencing the lighting designs and the envelope designs.

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And we're seeing lower energy use as a result of that. But we are not really seeing that same level of reduced energy in the mechanical systems and so that is one of the underlying drivers for this study and understanding how the buildings are actually being constructed and how the systems are working. So that we can understand how codes can be changed to actually decrease the energy use in the mechanical system beyond just the efficiency of the equipment themselves.

So, I ideally codes are targeting deeper and deeper energy savings and reducing energy use over time. So, a key research objective for this methodology, just to summarize, is to determine whether or not this is actually happening. Is there a relationship between commercial energy code compliance and actual energy use?

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And if so, what are those characteristics and designs that are driving the differences?

For example, and this is something that I'll be showing in some of our graphics from the pilot, but for example, do compliant offices use less energy than non-compliant offices? Is that compliance actually delivering lower energy use? And do compliant offices built to current codes use less energy than offices built to the previous code?

So, are we actually making progress? So, the important thing is is that this type of characteristics and energy benchmarking along with the code compliance, these all need the same core data. They need these detail characteristics, and they need the energy use. And once you get that core data you can analyze it in a number of different ways.

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And that's another key aspect of this methodology.

So, fortunately, in the northwest, and this goes for many areas, we have multiple stakeholders for this type of data and analysis. So, the overall approach is delivering a wide spectrum of value. So, the benchmark characteristics and understanding of the new construction practices that can feed into utility conservation, potential assessments. It can lead to better designs if the design community are accessing the data.

We also have a regional energy planning in the Pacific Northwest and so they are – the planners are very dependent on having a baseline to assess the conservation potential for the energy plans.

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We're also identifying major compliance gaps, which helps support enforcement, training, and education in general with benchmarking, new construction EUIs in particular, which is also very important for conservation potential assessments and also for developing outcomes based targets for new construction.

If we're looking at performance targets it's really good to have an understanding particularly for new construction. What are those

EUIs? What are we actually getting now? What should the programs or the codes actually be targeting if we are thinking that we may be moving in that direction at some point with outcome-based codes.

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And we're also informing commercial code development and program development, and this relationship between the code development and program development is important because the programs, the new construction programs are indexed to the codes, so they really need similar information.

So, ultimately, what this methodology is delivering is a compliance assessment along with an updated commercial new construction baseline, which will ultimately be delivered on a state by state basis with the opportunity for utilities to do over samples so that they can have an understanding of what the characteristics and energy use look like in their specific utility service territory.

And we're also providing marbling inputs because of the detailed level of characteristics, we're providing modeling inputs for savings estimates.

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When we develop new code we need to apply that to the baseline and have an understanding of what type of – what level of energy savings we're getting there.

Another key aspect of this methodology is that it's linked by building systems as opposed to dozens of individual codes. This is how we're moving away from the components and trying to understand things more on a systems level. So, we have three main aspects of this methodology. One is the compliance assessment, one is an enforcement assessment, which involved interviews with jurisdictions, and the third is an energy performance assessment.

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I'm only going to be discussing the results from the compliance assessment and the energy performance assessment in this presentation. But we're focusing on building systems rather than kind of more mechanistic reductionist approach for assessing straight code compliance, which was focusing on a sum of the compliance of many components, which doesn't really tell you a lot except that you have such and such percentage of compliance.

So, we're gracing more of a holistic approach, which is focused on the building systems that end up more of the overall energy use. And we're also looking at the larger ecosystem of code design, code enforcement, and the distinct design communities that are delivering those systems.

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And this is important because really when you're looking at changing buildings you're looking at changing behavior and changing behavior on the part of the designers, developers, contractors. And so, it's important to be looking at this compliance and the characteristics on a systems level so that you can then reach out to those communities of these different designers and have a good understanding of where the potential and opportunities are in those specific areas.

So, we're able to hone in on the key determinants of energy use in the different systems to understand the direction for potential changes. So, each of these spaces is focusing on the same building system, specifically so the findings can be compared across each of these phases of the methodology.

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Because we're trying to understand the relationship between the characteristics, the compliance, the enforcement that did or did not lead to compliance and the ultimate energy performance of those same buildings.

So, for each of the major systems we're focusing on high value aspects of those systems. And these are the areas that we decided to look at for this study based on research into previous studies and our own experience with commercial building design and evaluation. They also align somewhat with the sensitivity analysis that PNNL did –

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and in future, larger studies with working groups we're going to be looking at the choices here in more detail, and we may revise these.

But, essentially for the envelope we're looking at the overall UA based on the individual component UA. So, we're gathering all those details to develop the overall UA. We're also looking for a sample for the mechanical system, we're looking at equipment efficiency, economizer compliance, heat recovery and controls.

For service water, which is really just a subset of mechanical, but we broke it out for this study, we're looking at equipment efficiency, pump scheduling and pipe installation. And for lighting we're looking at both interior LPD and exterior lighting power and we collected data on controls.

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So, here's a flow of the compliance assessment steps. We did do a sample design for the entire four states, but that was just an aspect of the pilot study to test out an approach for doing larger scale sample design using Dodge new construction data. But ultimately, we targeted 15 to 20 sites in Washington State and we ultimately ended up actually doing audits on 12 sites.

And it was a mix of multi-family offices, retail schools and warehouses. So, we developed a detailed characteristics audit protocol that was based on some previous new construction baseline studies that have been implemented in the northwest.

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The last one that was done was about ten years ago. So, we do have some historical data, but the future studies in the northwest would be a pretty major update to the data that we had previously on a state level.

Then we implemented our recruiting, which we had a similar approach to the approach that Mike described. We used the contacts from the Dodge data and did cold calling. It was also difficult in this pilot and we're looking at some other alternatives as well. Potentially coordinating with the jurisdictions but also maybe coordinating with the utilities who are all key stakeholders for NEEA and could potentially be involved in the implementation and support of the research.

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So, we gathered as much information as we could from the building as well as, in some cases, from the building departments, and we implemented the detail plan and on-site audit for the 12 buildings. Then we assembled a new construction characteristics database for those 12 buildings and we calculated the LPD and the UA and did some other preliminary analysis on the results on the data that we actually collected from the buildings.

And then we did a compliance assessment for each of those areas of the major code sections and these compliance assessments were specific to each building. So, we were looking into the code and determining exactly what was required for each of these areas for these particular buildings.

[0:48:00]

So, now I'm going to talk about some of the results, and I would just like to emphasize that these are results from the small pilot. They are pretty interesting, I think, in some cases, and they really show what type of analysis we can do with a statistically representative sample. But they aren't representative of anything except for these 12 buildings in Washington State, but that was the purpose of the pilot.

So, in most cases for the actual compliance assessment we used a binary approach where it was comply or does not comply. And that's what this graphic is showing for each of the main systems.

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It's showing red for non-complying for that building for that system and green for complying, and then on the right we see a sum of the percentage of complying buildings for each of those sections and then also the complying percentage for the buildings overall.

In future studies we are considering potentially moving away from the binary determination at least in things like LPD and UA where we could have a spectrum of compliance. And that may be useful for understanding the impact of the compliance. But we do have the underlying characteristics, so even if we're looking at a comply, does not comply we're able to drill down deeper.

For example, this road here is really an example of how a straight compliance determination is not actually that helpful –

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because we determine the compliance for each of these systems based on the compliance of the seven components and then if any one of those systems was not compliant the whole building would be not compliant.

So, it also shows how the approach to the compliance determination really influenced the outcome, which, like I said, isn't actually very useful or important, which is what this graphic really shows. What does it actually – how does it help you to know that 50 percent of these buildings were not compliant? You could draw a lot of conclusions but it doesn't really help you to move forward to know what you really would need to do to change the outcome.

[0:51:00]

So, moving into some of the characteristics this is a graphic of the compliance versus non-compliance for the building key blocks, estimated, which is normalized by floor area. So, these are all of the buildings that we could provide enough data for this determination, this particular building did not have enough data for that.

The green is what we're actually seeing in the building. The blue is what was required, this is the allowance for that particular building based on the Washington state energy code. So, what we're seeing here is a little bit more useful information because what we can see is that across all of these buildings we are consistently, except in a couple places –

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in this building and this building on the right, we can see that we're almost always needing or exceeding the allowance or, in this case, improving on that UA.

So, this is useful information because if we have – if this is for only a small set of buildings, but if we were looking at this statistically across the whole state, we could draw some conclusions from it. For example, if we are consistently dramatically under shooting the allowance for the building key blocks then that probably needs to be changed in the code.

And we just currently don't have this type of information for new construction. We do have a pretty robust existing building stock assessment, –

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but CBSA, Commercial Buildings Stock Assessment, in the northwest it's done every five years, but we do not have a new construction specific assessment, and that's what this – these studies are actually going to fill that gap.

So, moving onto the mechanical subcomponent compliance, this is just for the mechanical compliance row that we had in that previous graphic, this is looking at it with a specific component for the equipment efficiency, the economizer, and the heat recovery. So, this is just an example of kind of drilling down, okay, this is not a compliant mechanical system, why didn't it comply? Was it the efficiency? Was it the economizer? Was it the heat recovery? Where are we really failing there?

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This graph is looking at the interior LPD light power density by building. And we are actually seeing where we have the blue as the LPD allowance for each of the buildings, and the green is the as-reviewed LPD working consistently a much lower LPD. And what we were seeing in the characteristics for these buildings is that I believe it was 100 percent of the buildings had some LEDs and many of them had a significant amount of LPDs.

So, what we're seeing is that – if we were to be doing this in a statistical survey we could surmise that we actually are seeing some market transformation with LEDs and we also are seeing these choices is by the lighting designers are delivering much lower LPDs.

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Which can actually be problematic in cases where there is a building that the designers are going the target performance route with modeling where they're actually saving a lot on the LPD via LEDs and unfortunately they can actually not be having as good of a building for the envelope and the mechanical system. So, these kinds of trade-offs it's important to understand what this construction is actually looking like so that we can understand the impact of – and potential risks of these types of trade-offs.

So, moving to the energy performance assessment methodology,

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ideally you want to delay at least 12 months and preferably 18 months or more before you get the build ready building. And in the case of the buildings that were in the pilot study they were already complete and in some cases they had been complete for quite a while, which also contributed to the difficulty in recruiting because the farther away from the actual completion and the building the more difficult it is to get a hold of the right people.

But, nonetheless, for purposes of the energy performance assessment we were able to go out and get at least 12 months, and in many cases 18 months' worth of bills for these buildings. So, we collected the billing data for both gas and electric from the relevant utilities. We did an analysis on the sites, looking at the particular site, trying to understand what type of energy use they would likely need to have, are we looking at 100 percent occupancy or not?

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So that we were really just looking at the viable sites.

And we determined the total EUIs for each of those buildings and then we used a tool called EVSIM to disaggregate the end uses and then the approach to this is to do pretty much a straight change point analysis to disaggregate the heating loads, the HVAC loads and then we're using a characteristic that we gather from the buildings that's just the LPD and the UA to disaggregate some of the other end uses.

Then we're taking both the total UA – I mean the total EUI and the disaggregated end use EUIs and correlating those with those compliance determination for these buildings for each of those systems.

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So, we have EUIs for each of those major end uses, and we have the compliance for each of those major end uses.

Then we did a benchmarking exercise where we're comparing the end use EUIs and the total EUIs to the same data from the 2006 commercial new construction baseline that we implemented in all four states and the northwest, and we were comparing it specifically to the relevant buildings for the Washington state portion of that study.

All of this is – they all really become critical inputs for tracking energy use over time because we do have this 2006 benchmark for all four states. Now we're moving forward into doing updated studies for these four states, –

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and then doing it in a way that we can move forward over time and actually be tracking this on a consistent basis and have a foundation for this type of analysis moving forward.

So, here are some of the results from this analysis. Again, it's from a small pilot, but it communicates the type of analysis we could do with a larger sample. So, we have these bars broken out into four of the building types; elementary school, medical office, retail grocery, that's because it was a big box retail included grocery, and then we also have small offices.

So, if we were looking at these bars for a larger study it's likely that we might look at all the individual buildings, just to see what we could find, but we would likely be looking at aggregates of the building –

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and trying to understand the relationship between the EUIs for the complying buildings and the EUIs for the non-complying buildings on an aggregate level.

But here we have them broken out into the individual buildings. So, the red bars are the non-complying buildings, and then there's a code for which system was not complying. And the green is a complying building. So, for elementary schools we're seeing two buildings that were 100 percent complying. They were using significantly lower energy – significantly less energy than the non-complying building that has done non-compliant with the water components and then also with the envelope.

So, we're not drawing any conclusions here that this non-complying building uses a ton of extra energy because it's non-complying in these two areas.

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But we could be making these kind of inferences with a larger sample size, and we could drill down to understand, okay, which systems are not complying? What could potentially be leading to this? And we'd be looking at that across averages of all of the buildings that we're looking at.

So, this is an example of understanding on the total EUI at level what could be contributing to this energy use, high or low. And what – how does the code relate to that? Another thing that we can do is even drill down below these systems and look at the actual characteristics and the particular design of some of these buildings and what the issues are there.

Another thing to note is just that, again, this is all actual energy use and we have some very low EUI buildings.

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This one is less than 20 KBTU per square foot, this small office is – looks like it's close to maybe 16 or 17. So, this is the same buildings and basically the same information except that we're seeing the disaggregated end uses.

And we have heating is the maroon bar, cooling is the blue, green is the fan energy, and orange is other, which we weren't able to do it for this pilot, but in future studies we're hoping to be able to disaggregate the lighting. So, other would really just be mainly process loads and plug loads and we would have lighting broken out separately.

[1:03:00]

This is important to see because now you're looking at a non-complying building versus complying building, and you can look at the stacked bar charts to see, okay, what systems are actually contributing to that difference? And in this case we see that the heating energy use is very high. We also have a large other category. There's not a lot that we can say about these distinctions in the pilot but just showing how we can actually look at the data is important.

In this case we're seeing not too much of a difference in the heating load. But again, it's important to understand –

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or to see that this is the kind of breakouts that we can look at. So, next this is the benchmarking component of the study. We're comparing the building EUIs from this small pilot to use at 2006 new construction baseline results for the state of Washington.

And the sites from the pilot study are the green dots and the red triangles. The red triangles are the overall non-complying buildings, and the green dots are the overall complying. The box plots represent the baseline core tiles with the minimum and maximum lines. And we also have the median. So, when we're looking at elementary schools, the line across is the median EUI for the all of the sites that were in the baseline study.

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We're showing the dots and the triangles to show the progress that we're making with the buildings that were built to a code that would approximately two code cycles later, two to three code cycles later. In a larger study we might not have individual dots. We would likely be showing the median from the 2006 baseline study and the median or average from our new study.

But what you can see is that this complying building – non-complying building for a school is right about the median from the 2006 study, which was buildings that were built in two to four years prior to 2006. And then we have these two complying buildings that are well below. And you can see similar relationships for the other buildings.

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So, in addition this is the same graphic, but I've added Washington state energy code target. So, this can show not only progress for the code in general, but also against targets. Washington State has a pretty aggressive target to reduce the energy use in residential and commercial buildings to 70 percent below the 2006 numbers by 2031. So, I've added this little dotted line for each of these building types.

This is the target. It's very low, as one would expect when you're reducing the energy use by 70 percent. This is legally required mandates, –

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so this shows where this target is in relation to the median of 2006, so it gives you an idea of how much we're actually reducing, and then it shows you where the non-complying and complying buildings fall on that spectrum.

So, we're also able to benchmark the end uses. This is a benchmark of the LPDs. These are the median LPDs from the 2006 study, and these are the LPDs from our pilot. So, they're dropping steadily and I would assume that they're going to keep going on that trajectory, but that is not necessarily a finding from this pilot.

So, that really covers the conceptual framework for the methodology –

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and also provides an idea of and a demonstration of the type of data and analysis we can get out of this approach that is fairly integrated and holistic and meets multiple objectives for multiple stakeholders. And the next steps for this methodology are to put it into practice. NEEA is launching the Oregon code evaluation in the fourth quarter this year. We're working with them on that study and then they are intending to, at some point, likely next year, move into Washington state and then eventually Idaho and Montana.

Pam Cole: Okay. Thanks, Poppy. That was great. Thank you, Mike. Both those studies were really interesting and got a lot of good questions that came in.

[1:09:00]

Before we go into the questions, I want to just touch on DOE's building and energy codes program resources, and out on energycodes.gov if you haven't taken a look at on the website a couple of things you might want to go take a look at.

Compliance software available, we have COMcheck, COMcheck web shows compliance to the ASHRAE 90.1 and IECC, the last three versions and current version of 2015 and 90.1 2013. We do have a help desk if you have questions related to the energy codes or compliance tools. We have code notes that are available on specific code items that you might be interested in taking a look at.

There's several publications, we do energy cost analysis, energy savings that are done by our energy modelers on a state by state basis and a national analysis. We have resource guides, and then we do a whole complete set of training materials.

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If you're a trainer or you're interested in the whole complete set of training, we have 90.1 and IECC training materials that are available out on the same page that you went to register for this webinar. Out on energycodes.gov.

Again, we're going to have these webinars every other month throughout next year. If you have any topic items that you think would be of interest, please submit them. If you didn't take down the reminder webinar email you can submit those topic items through our help desk, and the help desk link is out there on energycodes.gov as well.

So, at this time we're going to start into the questions. We've received a lot of really good questions, and I'm going to start off with the series of questions that we received for Mike's presentation. And Mike, if you want me to turn it back over to you as presenter, if you want to bring up any of your slides just let me know.

[1:11:00]

So, let's take a look at some of these questions here. So, one of the first questions that came in was, "How does a consultant ensure that the new design meets the energy code compliance without completing an energy modeling analysis?" Can you touch on that, Mike?

Michael Rosenberg: Sure. So, the majority of projects, the vast majority of projects don't use the performance path, they use prescriptive path. I understand that might be different in California, but the nine projects that we looked at were all prescriptive based projects. So, energy modeling analysis, I think that's what you're asking here for performance based compliance did not really come into play.

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Now, as we're rolling this methodology out on a larger scale, we are sure that we will run into buildings that have gone down the performance path, and we are actually testing a methodology to accommodate those buildings as well, and basically what it comes down to is for every measure the performance path defines a baseline condition.

So, for instance, you might've used higher mechanical efficiency in order to trade off for less insulation or something like that. In that case the higher mechanical efficiency becomes really the code condition and the less insulation becomes the code condition. So, then we just assess compared to those adjusted baselines, and we're working on that right now. So, I hope that answers the question. If it doesn't maybe type something back and I'll see if I can address it more directly.

[1:13:00]

Pam Cole: And we won't get through all these questions today, folks. If you still have a question that you'd like answered you could submit it through our help desk and we will get it directed to the proper person and make sure we get you an answer. So, the ones that we can, as long as the time that we can go through the series of questions that we received, we have received a lot of questions.

So, the next question for you, Mike, is, "Are the tabulated lost dollar savings on an annual basis?"

Michael Rosenberg: The savings I presented were – I presented the savings in two ways, in an annual basis and on the lifecycle basis. So, over the entire life of the building.

Pam Cole: Okay. "Were all of the savings calculations based only on three conditions? Compliant, 50 percent compliant, zero percent compliance, or did you use any intermediate metrics such as 75 percent compliant to calculate a total savings?"

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Michael Rosenberg: Yes. Any intermediate condition was accommodated. Depending on what the measure was, for the most part by simulating three conditions you can develop a regression or someway to identify what every in between value would result in a lost cost savings. For some measures we had to do more than three. But, yeah, it's not that they just pick the closest one, you know, code below or worst. They actually identify the exact condition and as best we could we give the direct lost energy cost savings for that condition.

Pam Cole: "With a building life savings of around $45,000.00 plus and an annual savings around $3600.00 were you figuring that the estimated life of a building is only 13 years?" I think this was on one of your slides.

Michael Rosenberg: Okay. So, the $46,000.00 is not just the sum of the annual savings.

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It's the lifecycle cost savings. The present value of the savings over the life of the building. So, using engineering economics savings in the future is discounted, not worth quite as much as savings today. So, it's not a straight multiplication. The measure lives that we were using differed depending on the measure.

So, if it was an envelope measure like wall insulation or windows we assigned a 30-year life to it. We didn't go any higher than 30. Some studies use 40. But we stayed at 30 for this. It actually turns out it doesn't make too much of a difference once you get that far out in the future whether you use 30 or 40. And then for things like building controls and mechanical equipment and lighting fixtures I believe it was 15 years.

One other thing to notice – I want to mention, Pam, is – or I want to mention and Pam maybe can take care of this, what I didn't put in this presentation is a link to the technical support document, the full report on this study, –

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and I don't know if we can add it before it goes up on the website, but that would probably be good because there's a lot more data in the full study than there is in the slide show, of course.

Pam Cole: Yeah. We can get that added. We'll add that to the presentation. That's not a problem. Another question that came in is, "How many tons was the equipment oversized per building?"

Michael Rosenberg: Oh boy. That I couldn't tell you, and I see the next question's kind of the same from the same person or what percent over sizing. I don't know that offhand. I know that we did get some feedback that there was oversizing over 200 percent on some of the buildings, but I couldn't tell you an average or even the range without doing some lookup. Sorry.

[1:17:00]

Pam Cole: Another question that came in, "Was the saving for mechanical systems based on installation cost or operation cost? If both, what is the breakdown?"

Michael Rosenberg: The savings, in all cases is based on operation cost.

Pam Cole: Okay. Couple more and then we'll get over to Poppy, and she can answer some from her study. "What specific items are you concerned about regarding having just one site visit? Or did you have any?"

Michael Rosenberg: Well, yeah. It depends on when that site visit is. So, I think I mentioned this during the talk that if you go out there once the building is completely constructed. You're not going to see a lot of the envelope components, the insulation, the slab insulation, the wall insulation. If you go out there too early you're not going to see a lot of the controls fully implemented yet. So, that's the problem. There's not one time that's really best. It's a lot of different times.

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Pam Cole: All right. We received a lot of good comments as far as they thought that that was an excellent study that you did, Mike. And Poppy, I have some questions for you. We'll switch it over to you so you can address some from yours. First question that came in when you were presenting was, "Did you look at fenestration solar heat gain coefficient as part of your – one of your options or your paths?" When you were going through your prescriptive path I believe.

Poppy Storm: Yes. We did.

Pam Cole: Next question, "Was there any process in place to evaluate the cost of compliance versus the projected savings? Is there any way to determine if the projected life cycle savings is greater than the cost of compliance?"

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Poppy Storm: If I understand that question correctly, that's pretty much along the lines of what the PNNL study is looking at, and I would say that with the characteristics that we're collecting with our study that you could actually likely do that type of analysis. It's not a part of our current methodology, but it's something that NEEA's going to be looking at and we're going to be discussing that potential with

PNNL just in terms of insuring that we're collecting the right inputs to insure that that is a possibility in the future.

Michael Rosenberg: Can I add something on this?

Pam Cole: Sure. Go ahead.

Michael Rosenberg: So, I think this question is more about is the code itself cost effective? Is the way I'm reading this.

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Is the projected life cycle savings greater than the cost of compliance? While that wasn't done in either one of our studies, we at PNNL do do that all the time. So there is a study for ASHRAE standard 90.1, each of the last two versions and the IECC for residential and potentially for commercial also that looks into each new round of code and the changes that were made and compares that to the cost of those changes and the savings from them and determines the cost effectiveness of the new version of the code. So, that is also available on the BECP website. If that is the question you were getting at. So, hopefully we answered it.

Pam Cole: That's good. 'Cause I mentioned that it was a resource. I'm glad you clarified that about those studies. So, this question could be for both of you, and you might've cleared this when you were speaking about it, but the question was,

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"Were all studies conducted on buildings built using the prescriptive compliance path or were any buildings studied using the performance based path using energy modeling?"

Michael Rosenberg: Well –

Pam Cole: Either one of you.

Poppy Storm: I'll answer.

Michael Rosenberg: Yeah.

Poppy Storm: I'll answer that first. There was 1 of the 12 buildings that went the performance path in our study, but the rest of them went the prescriptive path and we do find that to be the predominant approach. At least in Washington State and in most states in the northwest.

Pam Cole: This question's for you, Mike. "Are these pilots from DOEs or code compliance and energy audits extended to other states?"

Michael Rosenberg: Yeah. So, that's the project that I was talking about, the $1.7 million project that IMT is starting on.

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It is going to be extended to four different states, Nevada, Iowa, Nebraska and Florida I believe are the states and you're looking at at least 250 buildings in this study.

Pam Cole: Okay. Poppy, this question's for you. "What was the typical mechanical systems allowable energy use intensity for your study of those buildings?"

Poppy Storm: Can you repeat the question?

Pam Cole: "What was the typical mechanical systems allowable energy use intensity for your study of those buildings, of these buildings?"

Poppy Storm: I can answer part of that, mainly my response is we didn't have a target or allowable EUI for the mechanical systems.

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We were just looking at what the actual EUIs for the systems that we found, but it is an interesting question, especially if we're looking into the future and having outcome targets for the whole building or specific systems in the building. But it wasn't something that was a part of our study, and there isn't any allowable or non-allowable EUI for mechanical systems for the Washington code.

Pam Cole: Next question that came in is a good one, "During billing analysis was commissioning verified to ensure building systems were operating as intended at or near their rated efficiencies?"

Poppy Storm: So, we did look at commissioning and wherever possible we verify that, –

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but I will say that that is actually a difficult thing to confirm especially after the fact if you're looking at it six months to a year or longer after. Because a lot of that documentation is not available, but it was part of the methodology and it's something that we plan to check and we're hoping to be able to – they'll be more successful in the future if we can work with the jurisdictions more closely.

Pam Cole: And another question for you, Poppy. "What was the name of the tool that you used to disaggregate the end uses and was there any sub-metering?"

Poppy Storm: The tool was called EVSIM, it's E-V-S-I-M, and it's a tool that was developed in the northwest, and we use that to do the disaggregation. We did not do any induced metering for this study.

[1:25:00]

Pam Cole: Okay. We'll take two more questions here. Mike, this is a question for you, not sure you'll be able to answer it, but I'll throw it at you anyway. "Do you believe the 2018 IECC multifamily specific code will reduce the complexity of code compliance for a commercial building?"

Michael Rosenberg: Okay. So, I think this is in regard – there's a propose to the IECC to pull multifamily construction out of low-rise multifamily out of residential and high-rise out of the commercial provisions and create their own chapter. So, I think I understand the question, while I'm not sure I have an answer. I think it has the potential to reduce the complexity and to make it more suitable for multifamily in the long run. My understanding is they're just pulling out the same requirements that are in both of those sections now and combining them into a separate section.

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So, I don't think from a technical standpoint it's going to – it will make improvements to the appropriateness of the requirements, but I think in the long run it has the potential to do that, so I guess that would make it less complex. And then I suppose if you're just looking at multifamily and don't have to worry yourself with all the requirements of the other two chapters that don't apply to multi-family that's a benefit as well. So, thinking about it, yeah, I guess it would have a – it probably will reduce the complexity.

Pam Cole: One more question for you. "How will the 250 buildings going to be selected in your next study?"

Michael Rosenberg: Right. Actually kind of volunteer buildings. So, I am not selecting the buildings. That is a – IMT, Institute for Market Transformation, –

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and has teamed up with a bunch of other contractors to do this next study. It's not a PNNL study. We're going to be providing some technical support to DOE for that study, so we are not involved in the recruiting, and I don't know that a recruiting approach has been developed fully yet, so I can't really answer that question.

Pam Cole: Okay. Well, our time is up today, and we thank you everyone that's participated in our webinar. Again, we will be holding a webinar every other month, so take a look out on the training page on energycodes.gov. If you have any topic items that you think would be of interest please submit them our way. If you had a question that we did not get to and you would like to receive an answer, please submit them through our help desk. And we'll get you to the appropriate person to help answer that for you.

[1:28:00]

And at this time all of you can disconnect. Thank you for attending today's webinar.

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