Sustainable Energy Resources for Consumers Webinar on Building Design & Passive Solar Transcript

The following is a transcript of a Webinar recording on passive solar building design and solar thermal heating, which was presented on Nov. 30, 2010 for Sustainable Energy Resources for Consumers Grantees and sponsored by the U.S. Department of Energy. Watch the video recording.

Liz Doris:
Thank you so much. My name is Liz Doris. I'm a Technical Assistant Coordinator for the National Renewable Energy Laboratory, and the lab is supporting the SERC and WECC efforts through the Department of Energy and with the support of the Department of Energy. Also, with the support of the Department of Energy we've put together this webinar series that we're doing every two weeks on Tuesdays at this time which you will be sent an invite for every other week.

And also you can find out information about them on the SERC TA website, where you can find a whole variety of information about your SERC grants, and also about the technical assistance that's available to you. That website is kind of long, but I'm going to read it. It's www1.eere.energy.gov/wip/serc.html. And you can find a whole variety of information up there that DOE has put up on these. You can also get access to direct technical assistance where we'll try to respond to your questions directly, and you can email us at SERC_TA@NREL.gov, and we'll try to respond to those as as quickly as we can. We will be out of the office next week, Monday through Wednesday, so we will try to respond as quickly as we can, but please be patient with us as we get that going.

With that, I will say that although you can't speak on the conference call because it's being recorded, we do encourage you, and Andy, the speaker, really encourages you to ask questions. You can do that through the Live Meeting web access. If you look at the top of your panel, there are five buttons across the top. One of them is Q&A, and if you click on it, there's a window that says, "Type in question for the presenter." If you type a question there, Andy will be able to see that and he can either take a break from what he's doing and answer the question, or he's going to leave some time for questions at the end of the meeting.

We will be posting the recording of this on the SERC TA website that I mentioned earlier, and that hopefully will be within a week or two weeks. We have to get it transcribed so that takes a few days to do, but we'll get them posted up there. And so please join us in the next few weeks for additional webinars on different technologies.

But today we're going to talk about building design and passive solar, and solar thermal space heat. And Andy Walker with the National Renewable Energy Lab is going to talk about that. Andy has a PhD and is a professional engineer, and he's got years of experience modeling, monitoring, analyzing, and looking for alternative financing mechanisms for a whole variety of energy efficiency and renewable energy technologies.

And with that, I will pass it off to Andy.

Andy Walker:
Thank you, Liz. It's my privilege and pleasure to lead a discussion on passive solar heating with you this afternoon. And I would encourage you to use the Q&A feature of the website to please type your questions in and make it a little bit more interactive, and to try to make sure the webinar better meets your needs.

I'd like to start off with a little discussion of history. Passive solar heating is nothing new. In fact, it probably dates back to the first caveman that figured out that the south side of the cliff was better than the north side of the cliff in terms of finding a cave to live in. And we can see that a lot in Native American settlements and other prehistoric settlements around the world where it was not only a comfort issue, but also a practical requirement, because the old way of preserving food would be to lay it out to dry in the sun, and without solar access to at least the front of their homes or some courtyard where they could do that activity, they wouldn't be able to preserve food for the wintertime.

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The first written reference that I could find to it comes from a book called A Golden Thread by Ken Butti and John Perlin, where they describe 2,500 years of solar architecture. And the quote here is attributed to Socrates. "In houses that look toward the south, the sun penetrates the portico in winter, while in summer the path of the sun is right over our heads and above the roof so that there is shade." And if we look at some of these architectural models that are duplicating buildings from the 5th Century BC, we can see some of those features. Courtyards faced to the south, letting in the winter sun that is at a low angle. Then in the summer, the sun would be almost directly overhead so the overhangs that are hanging out over those windows, those eaves, would help to shade the windows.

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And then this progression of passive solar heating continues. You can see it in historic buildings that might be 400, 500 years old in Europe. But the sunny rooms of the house would be kind of limited to rooms that would have a high occupancy during the day. And you can see if you visit historic streets in downtown Denver or any downtown, you'll see how the houses on opposite sides of the street are mirror images so that they can maintain that the dining room and living room would be on the south side of the house.

But the single pane windows that they had in those days had too much heat loss. They used them for bedrooms, other rooms of the house. So it was in the 1940s that Libbey-Owens-Ford Company produced the first double pane window that didn't allow condensation to get in between the two panes that passive solar could really be made more accessible to other rooms in the house.

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This is an advertisement from a 1945 magazine, and the fine print down at the bottom says pretty as a picture, in this view from the living room of prefabricated solar home. Complete in package form, this home will be delivered to you by truck. So here even back as early as 1945 they're using the term solar home to describe this kind of thing. And if we look at the picture in the advertisement, we can see some of the same features that persist to this day. That is the large south-facing glazing—the overhang over the glazing to block the summer sun. And if you look at the floor you can also see it's made of a massive tile that can conduct that heat into the mass and store it to heat the room at night.

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A lot of times when people hear that there's going to be a passive solar home built next to them or something, they automatically come with a preconceived notion of what that home is going to look like, but really the features that we'll discuss for passive solar heating of a home can come in any different style, and this slide features four of them. The one in the upper left is a Victorian style home in Denver that would fit right in in a neighborhood with other historical or Victorian style homes in it.

The one in the upper right is kind of southwestern style or pueblo style, and this is very common and very popular in the southwest. And since the southwest is a good environment for passive solar heating, a lot of the best examples for passive solar architecture that we have are the southwestern pueblo style.

The one in the lower left is what I would call an arts and craft style. And the one on the lower right might be kind of hard to classify, but it's certainly of a modern design. So these are all passive solar buildings. They're homes that have passive solar as a very, very large percent if not all of their space heating requirements, and yet they all look very different. So I just want to make the point that passive solar heating features can be incorporated into any style of architecture.

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Whether a building can use that passive solar heat or not depends on what's happening inside the building. A lot of commercial buildings are already heated by the computers, lights, other machinery. So the passive solar heat is not necessarily welcome in a lot of these building types. But residential buildings are probably the best for passive solar because they're not generally packed full of people and equipment to keep them warm, and the passive solar heat is welcome in wintertime to offset what would be required to heat the home.

Some commercial buildings have the air conditioner running all year long, twelve months per year, to dissipate the heat, and they can't really benefit from the passive solar heat. But in general, residences all across this country can.

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Basically there are three passive solar strategies for getting the heat into a building. One is direct gain. This is simply putting windows on the south side of a room. Simple and

inexpensive. It does entail some issues of glare and thermal comfort which we will discuss. It's suitable for the residential applications that are the topic of this webinar. And it's suitable for a lot of spaces in other types of buildings, too—circulation spaces or hallways, or atria that people just have to walk through. Don't necessarily have to sit in and work in. But it's generally suitable for workspaces because of the overheating and glare issues associated with direct solar heat gain.

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In this case, sunspace is often considered. It is an unconditioned space usually on the south side of a building, or certainly with access to the south side of a building. It's allowed to get a little bit too hot during the day, a little bit too cold at night, but by allowing the temperature of the sunspace to fluctuate, it's able to make a positive contribution to the rest of the building. And a Trombe wall is like a sunspace without the space. It's a massive wall, either concrete or masonry wall, built right behind the glazing. Since the wall is opaque, it provides privacy and the mass of the masonry behind the glazing tends to smooth out the heat delivery over time. And can accept heat over the course of the day, and deliver that heat into the room over the course of twenty-four hours.

So we'll discuss all three of these. We'll look at some commercial buildings, but then also consider residential example of all three of these types of passive solar heating strategies.

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Building orientation is probably the principle strategy to consider when designing a passive solar building. And by the way, it's much easier to incorporate passive solar heating into a new building design than to come back and retrofit existing buildings.

When the tax credits were in effect from 1981 to 1986 we did see a lot of people adding sunspaces and other passive solar features to existing buildings, but really the focus of the discussion should be how to build a building in the first place with these passive solar features in mind.

And so before the footprint of the building has been determined, we can consider the building orientation.

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Here in most of the U.S. the sun can be found somewhere in the southern sky. In the wintertime, it's very low in the sky. It might only be 25º or 27º off the horizon at noon on the winter solstice. And the sun is always low in the southern sky in the wintertime so it hits principally the south side of the building. That's why the south-facing surface is the one that's of principle interest to passive solar heating strategies.

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If all we were concerned about was heating in the wintertime, then that would be all we needed to think about, but we also have to think about cooling in the summertime.

Keeping the solar heat out when we don't want it is just as important as letting the solar heat in when we do want it.

In the summertime, the sun goes almost directly overhead. It might be 75º or 77º off the horizon at noon on the summer solstice. So in the summertime, the surfaces of the building which gets the most solar heat are going to be the east side, the roof and the west side. And so by stretching out the building from east to west, we can reduce the surface area of the east and west side, increase the surface area of the south side, and thus have a building that will intercept more solar heat in the winter when we want it, and reject more solar heat in the summer when we don't want it.

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This figure shows the solar heat on different surfaces. Horizontal would be the flat roof, east and west-facing surfaces, and north-facing surface, and the south-facing surface. You can see that the north-facing surface receives the minimum sunlight in any month, and generally the sunlight does not directly hit the north side, so although the north side is very important for daylighting, it's not important for passive solar heating.

East and west side, we can see that they do get a lot of solar heat in the summertime, but only about half as much in the wintertime. And this figure is specific for Denver, but pretty typical of most of the continental U.S. And then the flat roof receives a significant amount of solar heat in the summertime and minimum in the wintertime.

And then the final curve that we haven't considered yet is the one that's labeled south. And notice that it has a completely different shape than the other ones. So the solar radiation on the south-facing surface is the maximum of over 900 BTUs per square foot per day in January and December. Then a minimum of about 300 in the summertime. And this figure does include the effect of an overhang geometry to shade that south-facing surface in the summertime.

So that figure helps us to understand the importance of the south side as considered better than the east and west sides.

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There's no one single overhang geometry which is perfect, because the position of the sun in the sky is symmetrical between March and September, but the temperature is not usually here in Denver in March there's snow on the ground, and it's cold, and in September it's hot. So in March we would want the solar heat, but in September we would not. So there's not one single overhang dimension that'll work for spring and fall. But this is a useful criterion for designing overhang dimensions for winter and summer.

There are basically two unknowns in the design of the overhangs. How far the overhang sticks out from the building, and how far above the window it is. And so we can use two equations to solve for those two unknowns. We can use the equation for the altitude of the sun at noon on the winter solstice, and then the same equation on the summer solstice. By using those two equations as illustrated in the figure here, we can figure out what the dimensions of the overhang would be to provide complete sun on the winter solstice, but complete shade on the summer solstice.

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And then if you really wanted to perfect things for the spring and fall, you'd have to have an overhang which could move back and forth, and there are examples of that. A couple that comes to mind are moveable awnings that project out and can be withdrawn in the spring. And then another one is vegetated trellises, which naturally in the springtime they wouldn't have any vines on them yet, but by September, by fall they would. With a couple of ideas to have overhangs which change their properties from season to season.

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The photograph in this slide is of Silver Hill office building here in Golden, Colorado. And you can see that, first of all, they have stretched out the building from east to west so the south side of the building is very large, but the east side of the building as you see in this photograph is very small.

They also haven't put very many windows on the east side. And notice that the overhang discussion that we just had is specific to a south-facing window. On the east and west sides, the sun hits the window either first thing in the morning on the east side, or last thing in the afternoon on the west side. And during those hours, the sun is so low in the sky that there's no practical overhang dimension that would shade the window so that the overhang strategy is only suitable for south-facing windows, and as illustrated in this photograph it was only used on south-facing windows. The east-facing windows and the north-facing windows on this building don't have any overhangs.

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Some other ideas that are central to passive solar architecture. One is to push the living areas outside of the space. You saw a photograph of that visitor center at Zion National Park. And one of the strategies was to make permanent signage and try to push some of those visitor activities outside of the conditioned envelope of the building. And so outdoor living spaces in any climate can help reduce the footprint of the building and help reduce the need for space heating of interior spaces.

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Early in the day we used to experiment with different ways of moving heat around a building. We tried to set up convection loops where one side of a building would warm the air up, and then that air would circulate over to the cold side of the building and distribute heat in the building that way. That doesn't work. And the reason it doesn't work is because natural convection requires a temperature difference. That's exactly what you don't want in a house. You don't want one room that's 20º hotter than another room. You want the whole house to be at the proper temperature.

So really what that led us to is to introducing the solar heat directly into the rooms that it's suppose to heat, and not expect it to move around the house from one room to another.

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This figure illustrates one strategy to do that, which is to break the ridgeline of the roof and put in a clear story window there. That will allow sunlight to come all the way in and hit the interior surface of the north wall of the building. So that's delivering the solar heat all the way over to the north side of the building, and distributing the solar heat over the space.

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The photograph here is of Louisville Daycare. The architect was Mike Nicholas. So you can see how he's got passive solar features on the south wall of the classroom, but also the clear story building that transmits light through a double-loaded corridor down the middle of the school and into the north-facing buildings.

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Here's a photograph of that kind of clear story in a residential application. You can see the roofline is broken in a cathedral ceiling here. It could also be structured with attic space under the south part of it, but here it's got a cathedral ceiling. And a cathedral ceiling doesn't allow you as much volume to stuff insulation in as an attic does, but by using structural insulated panels or a truss system instead of rafters to form that roof, you can get basically whatever R-value you want into the cathedral style ceiling.

It does give a place for hot air to collect up there at the top of the cathedral ceiling. If the ceiling was flat, the heat would distribute over the room pretty well, but by putting a cathedral ceiling in a house, we allow a place for the hot air to collect and not distribute around the lower parts of the house.

So what you see in the very upper left-hand side of this photo is some fan intakes. That would take a little bit of fan energy, so it wouldn't be completely passive, but a fan in this example, those fan intakes circulate air down to the basement. That sets up a loop to help mix up that heated air into the rest of the house.

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Here are some schematic diagrams of the different things that we've considered so far. Sun tempered would just be a south-facing window. We might consider a double thickness of drywall, or at least ½" drywall instead of 3/8th" drywall to get a little bit more mass into the building. But basically nothing that would cost significantly more than building a house in any other way. That's called sun tempered. Then if we add some mass in the form of a concrete slab, or masonry work, then we can call it a direct gain configuration.

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We discussed sunspace, and this figure shows how the sunlight can come in and heat up the mass of a sunspace. This figure also shows how you might have a fan at the top and the bottom of the sunspace to allow hot air to circulate into the room behind it. And then a thermal storage wall would be a massive wall built directly behind the glazing.

The modeling that we did with regards to the operation of vents in thermal storage wall has indicated that it's better not to have that kind of air circulation through the thermal storage wall. And the reason is you need a high temperature on the outside of the wall to cause a conduction of heat into the mass. The outside surface of the thermal storage wall might get up to 140ºF during the day, and you need that high temperature to cause the conduction into the mass so that you have that heat for use at night.

If you were to ventilate that space and allow the hot air to go directly into the room, then the Trombe wall or the thermal storage wall would never get hot enough to store the heat for use at night.

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Here's a photograph of a small building at our laboratory which uses the direct gain strategy. You can see that they built a good overhang over the office windows, and in this photograph which was taken in the summertime, you can see that the overhang is completely shading those south-facing windows in the offices.

But in the wintertime the sun would come in those office windows, and a lot of times when I visit this building, I find that occupants have closed the blinds because they don't want the glare, and they don't want to be sitting in a patch of sunlight coming through the window.

The second row of windows is above the central corridor, so like the circulation spaces that were referred to earlier, they should be in a suitable place to accept the direct passive solar heat gain without any consequences.

And the third row of windows is into some hybrid laboratory space. That also is coming into the space so high that it's not hitting anybody's workspace and doesn't seem to cause any problems.

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This is a photograph of my colleague, Jeff Dominick. He's my poster child for passive solar design. You can see he's got a cardboard box over his monitor so that he can try to defeat the glare of the sunlight coming in the window.

Another phenomenon that you want to avoid with the positioning of windows is backlighting. Basically any subject with a window behind it appears only as a silhouette, so if there's any kind of display of artwork or directional signage or informational signage or anything like that, you have to be careful not to defeat that with glare from sunlight coming directly in a window or backlighting.

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This is a photograph of a sunspace on another building here at our laboratory, the solar energy research facility. And again, we don't try to maintain comfort conditions in this space at all times. It gets a little bit too hot and a little bit too bright in the afternoon, and

a little bit too cold at night, but by allowing the temperature to fluctuate, you can see the air vents which can allow it to reduce heat loss off the south side of the building, and also deliver useful solar heat to the building.

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This is a thermal storage wall, or a Trombe wall in the shipping and receiving bay of the same building. There's one thing that's wrong with the design of this Trombe wall, and that is that it doesn't have an overhang. This photograph was taken when the sun is high in the sky in the summertime, and if it would have had an overhang, we could have provided some shade there to reduce the amount of heat that comes in in the summertime.

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Then I'd like to discuss these strategies in residential applications. This is my home in Golden, Colorado, where we've tried to implement a lot of these features. And you can see on the roof we have an evaporative cooler, 2.7 kilowatts of PV, and evacuated tubes for solar water heating.

These are other strategies to use for solar energy in a residential application. And our topics of other SERC webinars, which I'd encourage you to tune into to learn about those technologies. But lower on the building we can see a direct gain into living room, and then two sunspaces which we can discuss in a little bit more detail.

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Direct gain in a residential application usually doesn't cause any problem the same as it would in a commercial workspace office environment, and that's because if somebody's uncomfortable because they're sitting in the sun, they can easily move to a spot that doesn't have sun. They also have control over it.

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In this photograph, the blinds on one of the windows are down, but if somebody wanted to control how the solar heat that was coming in locally, they could easily do that with blinds or drapes, or shades. Or by moving to another part of the room which doesn't have the solar heat gain problems.

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There are two sunspaces on the south. The one on the left was part of the original 1978 design. The interior of that sunspace is shown in the photograph. On the left here you can see the windows. There's an overhang over the top of the windows. There are blinds to control privacy and shade. And then there's mass in the room to absorb the solar heat when it's available, and release that heat at night.

The sunspace on the right was one that was constructed more recently and incorporates a Trombe wall in the lower windows, and direct solar heat gain in the upper windows.

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This photograph shows the interior of that sunspace, and you can see the Trombe wall's below the 28" sill height, and then regular vision windows above that. This Trombe wall incorporates a thermal storage product from DAL called DAL interface, which was a eutectic salt which stored energy through a change of phase rather than an increase in temperature.

Though thermal storage is an important aspect of any passive solar design, and people have typically used massive elements like concrete, masonry, brick, stone to store that solar heat, that requires a lot of surface area for that heat transfer to occur. And it's often hard to pack that much surface area into a space. Really, the perfect type room for that would have a lot of articulation, a lot of interior brickwork or something like that.

The trouble with mass is that it stores heat by increasing temperature. And as we discussed earlier, it's a nice uniform temperature that you want. In order to drive heat into mass, the temperature would have to be much higher during the day, then that would cause a conduction of heat into the mass, and then as the temperature of the air gets cold at night, then that heat conducts out of the mass. But without that temperature difference – hot day, cold night – we wouldn't be able to drive the heat in and out of the mass. And that's what we don't want. We don't want a hot day and a cold night. We want the room to be uniform temperature all year round.

The water helps out with that by reducing the temperature differences as required to drive heat into the mass. And that's because it's not only by conduction, but also by convection that the water can move around in a storage tank.

I've seen a good example of that at the Society for the Preservation of New Hampshire Forests in New Hampshire where they have tubes of water in the office space. They have a pan under each tube in case it were to ever start leaking, but that building has been operating since the '80s without any problems. And I talked to the employees in that building recently, and they really like it.

Back in the '80s I was also responsible for dismantling a lot of water storage that had been built in houses previously, and I could see a lot of the problems that arise with just trying to maintain water. Keep nasty stuff from growing in the water. Keep the water from leaking out. So water hasn't really made it into the market as much as its advantages might have indicated that it might have.

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Phase change materials such as the DAL interface panels that we saw in the previous slide are coming onto the market. And most of the drywall manufacturers have some research underway into incorporating phase change materials into drywall. And then that would be a very useful product once that becomes available to help us smooth out the temperature fluctuations in a passive solar heated house.

A Professor named Ival Salyer at the University of Dayton in Ohio is the leader in that research of what kind of phase change materials would be able to be incorporated into drywall.

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Though it's very important to admit the solar heat into a building in the wintertime and to distribute it throughout a building, and to store it for use at night, but equally important is to keep the solar heat out when we don't want it, and so this slide kind of stresses the importance of strategies to keep the solar heat out in the summertime when we don't want it.

One strategy centers around the properties of window glass. The two most important parameters for passive solar heating are the heat loss coefficient, also known as the U-value of the glass, and the solar heat gain coefficient which is the fraction of the solar heat that makes it through the glass by any number of mechanisms, including getting absorbed in the glass and reradiated out into the room. So it's more than just the transmissivity of the glass. It has a term called the solar heat gain coefficient.

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Strategies to improve the U-value include using multiple plane gains. We already discussed how going from single pane to double pane was necessary back in the '40s to get any kind of passive solar effect. But now using coatings to reduce the emissivity of the glass, those are called low Es coatings. To put a gas that has a lower conductivity than air between the two panes, such as argon filled windows are another strategy to reduce the heat loss.

And suspending a third pane of plastic film in between the two glass panes is the strategy that's used in the windows that have the lowest U-value, or the lowest heat loss coefficient on the market.

So it's very important to specify a window that has a low U-value. That'll save energy even at night when the sun's not shining. But the more coatings that we put on a window and the more panes that we put into a window frame the more solar heat gain that we block, so the lower the solar heat gain coefficient goes.

But most window manufacturers do have products which have low U-values and high solar heat gain coefficients, and those are the terms that you want to use when you're talking to your window designer or whoever it is that's providing your windows. Tell them that you want a window with a low U-value and a high solar energy gain coefficient for the south side of the building.

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One interesting development, we incorporate two of these types of windows in our new building here that Liz, and Vicky and I are sitting in, that changed the window properties in response to either environmental conditions or a controlled signal. Electrochromic windows are windows which change their appearance in response to an electric control

signal, and that can come from a thermostat or from a building control system, to tell the window to turn a tinted shade with a lower solar heat gain coefficient when the room is getting too hot, and to turn clear again when the room is getting too cool.

Windows that respond to the temperature of the window itself are called thermochromic windows. They turn opaque when they get too hot. And there are also photochromic windows which change their properties in response to the intensity of the sunlight that's hitting them.

So photochromic, thermochromic, and electrochromic windows are windows that we expect to come on the market very soon, or that are already on the market in some applications.

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We already talked about the importance of overhangs to block the summer sun. And we mentioned how the sun is maximum on the roof of a building, especially the flat roof of a building in the summertime. So coatings that reflect that solar heat off the flat roof of a building also yields savings in terms of air conditioning energy.

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And the topic of this webinar is not daylighting, but it's so closely coupled to the passive solar heating strategies. In my opinion, daylighting is one of the principle pieces of passive solar light rather than passive solar heat in buildings, so I think it's important to go over some ideas of daylighting. Also as we admit passive solar heat into a room through direct gain, we're introducing the solar light whether we like it or not. So there are a couple of things to consider.

The objectives of daylighting are to admit the natural light into a space, but also to control and distribute it for a nice uniform lighting level. Avoid backlighting of any signage or displays, and avoid veiling reflections. If you can see the reflection of a window in a computer screen, that's going to be very annoying to people because it's going to tend to veil the image on the computer screen. Same is true of a television screen in a living room, or anything like that. So then what we try to do is position something like a big screen T.V. where the people that are sitting there watching that cannot see the reflection of the window in the T.V. And then in order to get any savings, we would have to control the artificial light in order to dim it back.

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Skylights are very effective. They're shown used here in a cafeteria at a school. Light shelves are another strategy to bounce the light deeper into the north side of a room. We can see that on the solar energy research facility here at our laboratory.

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Roof monitors or clear story windows are an excellent way to introduce light high into a space, and it has time to diffuse before it gets down to the floor level. And again, we'd need controls to automatically control the artificial light in response to that. It's pretty

common to walk into a building with excellent daylighting, but also to see all the artificial lights coming on. So these kinds of daylighting controls are available in both commercial and residential applications. Shown here is more of a commercial strategy of mounting the sensor in a roof.

A lot of times in residential applications the daylighting sensor would be integrated into the switch on the switch plate so that if there's enough natural light in the room, the light won't come on.

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Passive solar is actually a pretty challenging thing to analyze compared to photovoltaics or solar water heating. For example, with photovoltaics, it's pretty easy to predict what the performance of it is going to be. Each kilowatt of PV that you install is going to generate around 1,500 kilowatt hours of electricity per year. But passive solar heating, it's impossible to come up with those kinds of rules of thumb about how the technology is going to perform.

There are handbook methods that are available, but those handbook methods really were popular before the computer was so commonplace. Nowadays everybody uses software to both design the passive solar elements, and to estimate the performance of them over time.

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Here's a list of some that are typically used. The DOE-2 computer program started in the late '70s by the Department of Energy, is still under development but recently merged and restructured so that Department of Energy's effort is going into developing the second product on this list, the Energy Plus computer program. eQUEST is a user interface that was produced by – this guy's name is escaping me right now – in California funded by the California legislature to put DOE-2 into a user friendly form. So eQUEST is probably the most accessible way of using these computer tools. It's available for free download, so if you just Google on eQUEST, you'll find the website to download that computer program.
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It's made easy to use, but it's still got a powerful engine for modeling commercial buildings. What might be more appropriate for residential buildings is Energy-10 which is a similar approach, trying to make a user friendly frontend for a more sophisticated analytical engine. And it's appropriate for smaller commercial buildings and easier to use than eQUEST.

For example, in order to use eQUEST you have to step through a wizard that involves several input screens. With Energy-10 you only need five pieces of information to get started with your house model. You need the square footage. You would need the number of floors. You'd need to select a mechanical system option, whether you had air conditioning or not. You'd have to select a climate file. You have to specify the utility rates. And then you could run, and Energy-10 will automatically fill in all the wall properties, and window properties, and other things with default values. Then you would ideally get back in there and readjust all those assumed default values into things that actually represent your actual building design. So for small buildings less than 10,000 square feet, or for residential buildings, Energy-10 is probably the best tool on this list. It's not free. I think the license is $250 from an organization called Passive Solar Industries Council.

And then two tools that I wanted to talk about a little bit because they're kind of the future of where building energy modeling is headed is BEopt, which is Building Energy Optimization for residential buildings. And then Opt-E Plus is its older brother for larger commercial buildings.

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The photographs on this slide are of the Great Sand Dunes monument. What you see in the photograph on the bottom is the front of the building, and if you look at the left-hand side of that you'll see the two restrooms, the women's room and the men's room. It looks like a row of windows along the south side there, but those are not windows. That's a Trombe wall. That's the women's restroom on the other side of that, so the Trombe wall provides both passive solar heat gain, and also privacy.

There's a couple of skylights to let daylight in, and then a row of windows over the mechanical chase between the men's room and the women's room so the sunlight would come through that second row of windows and warm up what would be the south wall of the men's restroom. Then the image in the upper left-hand side there basically shows the computer model of that. This was put together using a DOE-2 computer program.

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Another example in a real small visitor's center. I like this example because it shows a lot of different features that have been integrated into this building. This is a small visitor's center at Jamaica Bay. It's a national park near New York City. And they've used direct gain on the south sides of the building. You can see the overhang to provide some summer shade in both the office area to the right-hand side of the building and also the display area to the left-hand side of the building. There's a Trombe wall right on the center part of the south side of the building.

And the Energy-10 computer program was used to predict the energy use of this building, and those measures combined with other measures in the building reduce the annual energy cost from $20,000 to about $13,000 in this example.

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An example of the eQUEST computer program used to analyze housing is the zero energy houses at Fort Campbell. Through a combination of superior insulation and mechanical system efficiency and rooftop photovoltaics, they're able to get the design down to the net zero use.

So eQUEST is a more difficult program to use, but able to accommodate more of these details of the building, especially the mechanical system options. It probably does a better job of handling a lot of the passive solar strategies.

I should have mentioned that the only one of these computer programs that I have experience with which can actually model a Trombe wall is the DOE-2 computer program. So the newer versions of eQUEST, the newer versions of Energy-10, despite the fact that they've come out since that, I don't have a good model of the Trombe wall, what they do for direct gain and sunspace type passive solar heating design strategies.

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Just continuing that eQUEST example, you can see the kind of results that you could generate with the eQUEST computer program. You can model the base case, model your energy efficiency case, and then by comparison of those two, calculate your savings.

In this case since the goal of getting this military housing down to net zero, almost all of the loads have been really hammered down through a variety of energy efficiency strategies. You can see the space heating load is the bright red on these bar charts. And the only load that really wasn't reduced was the green miscellaneous equipment, which is the loads that it was assumed that each homeowner would have plugged in.

So in terms of setting a net zero goal, this example helps to illustrate how the residential market is a really good place to set a net zero energy goal because the loads are not as intense as they would be in a commercial or industrial application, and the roof is usually big enough to accommodate enough PV to meet the load.

For example, in my house which we mentioned that 2.7 kilowatts is enough to provide about 360 kilowatt hours per month on average. And if we're really frugal, we can get our consumption down that low and demonstrate net zero use in our house there.

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This slide shows the screen interface for the Opt-E Plus interface. Each one of those little squares on the graph is a different combination of measures. Different wall R-values. Different ceiling R-values. Different window areas and so forth. And the computer goes through and evaluates all the possible combinations of all those parameters and figures out the one which minimizes life cycle cost.

So with total life cycle cost on the vertical axis of this graph, and the net side energy percent savings on the horizontal axis, you can see that that green spot corresponds to a minimum life cycle cost at a savings of about 25% annual energy use.

So this BEopt is a way to go through and try to optimize all the different strategies. It doesn't include all the renewable energy strategies yet, but it does include photovoltaics and solar water heating. The other cloud of squares that you see near the top of this figure is all the permutations that include different size photovoltaics systems. You get about another 15% annual energy savings.

So these are the kinds of tools that can be brought to solve specific design problems in houses, and thanks very much for your attention and your participation in the webinar. And if there are any remaining questions, we'd like to try to address them. I've had my Q&A box open. Haven't seen any questions come in over the course of the hour, but.

Liz Doris:
Andy, this is Liz. Can you talk a little bit about procurement for Trombe walls at all? Like what they should be looking for.

Andy Walker:
Yeah, procurement for Trombe walls. The example that I featured here – well, we considered a couple of examples. One was just a solid concrete wall that's poured before the windows were installed, behind where the windows would go. And then the other one was that DAL interface product. I guess they were installed in much different ways.

Ordinarily a Trombe wall would be part of the foundation design of the house. So while they're out there pouring the concrete for the rest of the foundation, they would pour the thermal storage part of the Trombe wall. Then as they're installing the windows later in the construction of the house, they would come and install the windows on the outside surface of that.

The surface that receives the sunlight, it should be in direct contact with the mass. Like I wouldn't want to put any kind of surface over the concrete there. The surface of the concrete could be painted black, or it could have a selective surface, which is a black and nickel film. The black and nickel film would be installed much in the way wallpaper would be installed on the concrete surface. Try to get a nice uniform adhesion so you don't have blisters or bubbles underneath it.

So yeah, the idea of installing a Trombe wall is really using the same techniques that are involved to construct the elements of the house. Just arranging them in such a way that they function as a Trombe wall.

And then the phase change panels, their incorporation into the Trombe wall is something different. In that case, the house is constructed, and then they can come in and install them later. You'd have a rough opening, same as a window, and you can install a window that could function as a vision window before the Trombe wall is installed. And then it's just a little bit of additional framing to come and install the phase change panels directly behind those installed windows. So I guess it's just the opposite of a poured concrete Trombe wall. The windows are installed first, and then the phase change panels are added later.

This is something that should be considered in the new design of a building. These are details that you'd want to work out with your architect. Probably the biggest thing you could do for success in passive solar heating would be to get an experienced architect that's familiar with the design tools, and by that I mean these computer design tools, to go through and really fine tune the details of the design.

Fortunately, you know, now that we're some thirty or forty years into the development of these passive solar strategies after, you know – we started out this discussion by saying how old some of these strategies are. But then probably starting in the '50s and continuing through the '70s, they were pretty much abandoned. This is because people didn't have to carry firewood into the house anymore. The thermostat automatically controlled the temperature so they were able to just basically forget about these things. They had the luxury of having a thermostat that would control the temperature automatically, and the utility bill was low so that didn't get their attention.

But I would say the passive solar strategy really got started in earnest in the '70s with advocates like Amory Lovins and Ed Mazria. Schools of architects coming out of the southwest here, but really all over the country started publishing books and developing the analytic tools to come up with good designs.

That was kind of a longwinded answer to your question, Liz, but I think that that's the answer. It is to have a selection criteria for your architect who includes passive solar design, and have an architect that can point to several completed examples of good solar design. Maybe talk to the occupants of those buildings.

The architect that designed my house, for example, had designed five or six houses that he called passive solar houses before he designed my house. And I think my house design benefited from all the mistakes he made in those other houses. So the selection criteria for an architect that has some experience.

And then the second procurement aspect would be the scope of work for that architect. And how that would be different is that you would include more hours for your architect to run these computer models. It might be another forty hours in his contract, or it might be another sixty hours in his contract for him to do the analysis that's required to come up with a passive solar design. But I think with those two elements, the selection criteria, and the scope of the work of the architect with, you know, the procurement of these systems rests.

Liz Doris:

Okay, and I think we have time for one more question. And Albert Weiss is asking, what sort of savings to investment ratio are you seeing with these passive solutions? What's the payback period for these measures?

Andy Walker:

You know, it occurred to me as I was putting these slides together that I didn't have information on that, so I might have to refer to the literature to see if we can find case studies where people have been able to do that.

I think the reason that I don't have that information handy is that it's not as straightforward as a photovoltaics or a solar water heating system where you can say yeah, I've got a $10,000 investment in this PV system. It's more like the investment of these measures is just tangled up with the cost to construct the house.

The Trombe wall is not an additional expense. It's just the way you build the south wall of the house. And the window on the south side of the house isn't an expense. It's just one that you moved from the west side of the house. So it really is difficult to isolate what the initial cost is of these measures. And one might say well, let's estimate the initial cost of a base case and then compare that with the initial cost of our passive solar case. And you can do that, but then your base case is a complete fabrication of what you would have done had you not done this passive solar route.

So I think the reason that the question is so difficult to answer is that passive solar, unlike the other solar technologies which are discussed in this webinar series, the passive solar investment is just an investment in the house itself, and it becomes difficult to isolate how much of that is an energy-saving feature and how much of it is just a window, or a roof, or a wall. So sorry I don't have the answer to that question.

Amy Bowen:
Thank you, Andy. It looks like we don't have any other questions. This is Amy from NREL, and I wanted to thank everyone for joining today. We will have additional webinars. The additional webinars will be probably a little more detailed and focused on residential existing retrofits. And we look forward to having you all attend those. Thank you very much.

Andy Walker:
Thanks everybody.

[End of Audio]