Energy Research and Development Division

FINAL PROJECT REPORT

Solar-Reflective "Cool" Walls: Benefits, Technologies, and Implementation

Appendix Q: Cool Wall Workshop Proceedings
(Task 6.2 Report)

California Energy Commission
Gavin Newsom, Governor

April 2019 | CEC-500-2019-040-APQ

Appendix Q:
Cool wall workshop proceedings (Task 6.2 report)

Haley Gilbert[1] and Sharon Chen[1]

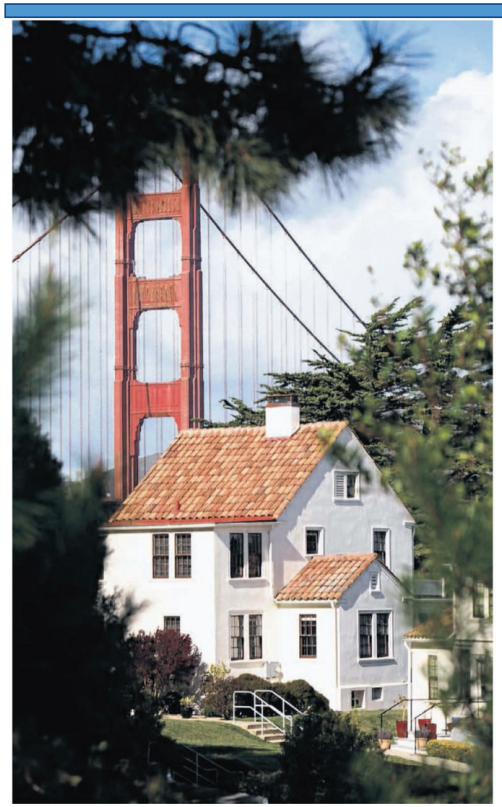
[1] Heat Island Group, Lawrence Berkeley National Laboratory

28 February 2018

Abstract

The research team hosted a Cool Wall workshop on 25 October 2017 to review and discuss its research portfolio with interested parties. This one-day event at Lawrence Berkeley National Laboratory was attended by industry, state government, federal government, utility, and building code stakeholders. There were 42 in-person and 6 remote participants. Presentations from the research team addressed energy and emission savings, changes to the urban environment, product aging, novel technologies, and infrastructure. These proceedings document the presentations and ensuing discussions.

LBNL Heat Island Group



Source: Lea Suzuki, San Francisco Chronicle, 10 February 2013

Solar Reflective "Cool" Walls: Benefits, Technologies, and Implementation

Workshop Proceedings

25 October 2017

1 Agenda

8:30 am – 5:00 pm Pacific Time • October 25, 2017
Building 15, Room 253 • Lawrence Berkeley National Laboratory • Berkeley, CA

Hosted by Lawrence Berkeley National Laboratory (LBNL) in partnership with University of Southern California (USC) and University of California, San Diego (UCSD)

Workshop and research supported by the California Energy Commission (CEC)

8:30 – 9:00	**Check-in & breakfast**	
9:00 – 9:15	Introductions, agenda and logistics	Ronnen Levinson, LBNL
9:15 – 10:00	CW Benefits 1: Simulated HVAC energy savings in an isolated building (Task 2.1)	Ronnen Levinson, LBNL
10:00 – 10:15	CW Benefits 2: Effect of neighboring cool walls on HVAC loads (Task 2.2)	Jan Kleissl, UCSD
10:15 – 10:40	**Discussion**	**Facilitated by Ronnen Levinson and Haley Gilbert, LBNL**
10:40 – 11:00	**Morning break**	
11:00 – 11:30	CW Co-Benefits 1: Pedestrian mean radiant temperature and thermal comfort (Task 3.1)	Jan Kleissl, UCSD
11:30 – 12:00	CW Co-Benefits 2: Urban climate impacts of cool walls (Task 3.2)	George Ban-Weiss, USC
12:00 – 12:30	**Discussion**	**Facilitated by Ronnen Levinson and Haley Gilbert, LBNL**
12:30 – 12:40	**Grab lunch**	
12:40 – 1:00	Overview of California's Electric Program Investment Charge (EPIC)	David Hungerford, CEC
1:00 – 1:30	**Lunch break**	
1:30 – 2:00	CW Technologies 1: Natural exposure of wall products (Task 4.1)	Hugo Destaillats, LBNL
2:00 – 2:30	CW Technologies 2: Self-cleaning and de-polluting photocatalytic materials (Tasks 4.2 and 3.3)	Xiaochen Tang, LBNL Jiachen Zhang, USC
2:30 – 3:00	CW Technologies 3: Fluorescent cool pigments (Task 5.1)	Paul Berdahl, LBNL
3:00 – 3:30	**Discussion**	**Facilitated by Hugo Destaillats and Haley Gilbert, LBNL**
3:30 – 3:40	**Afternoon break**	
3:40 – 4:00	CW Technologies 4: Retroreflective materials (Task 5.2)	Ronnen Levinson, LBNL
4:00 – 4:30	Advancing cool wall adoption through standards, incentive programs, and application guidelines (Task 6.1)	Haley Gilbert, LBNL Ronnen Levinson, LBNL
4:30 – 5:00	**Discussion & wrap-up**	**Facilitated by Ronnen Levinson and Haley Gilbert, LBNL**
5:00	**Adjourn**	

2 In-person participants

First Name	Last Name	Title	Organization
George	Ban-Weiss	Professor	University of Southern California
Paul	Berdahl	Staff Physicist (retired)	LBNL Heat Island Group
Brandon	Bethke	Vice President	Tempo Chemicals & Solutions
Paul	Bethke	Business Manager	Tempo Chemicals & Solutions
Michael	Biel	Vice President	The Ultimate Coatings Company
Chris	Boyce	Technical Formulator	ESI Tec
Sharon	Chen	Principal Research Associate	LBNL Heat Island Group
William	Dean	Climate Change Advisor	California Environmental Protection Agency
Hugo	Destaillats	Staff Scientist	LBNL Heat Island Group
Hannah	Erickson	Student	NA
Matthew	Eschenauer	Staff Scientist	Sherwin-Williams Company
Marlene	Garrow	Group Leader	Sherwin-Williams Company / Valspar
Haley	Gilbert	Principal Research Associate	LBNL Heat Island Group
Kathleen	Gisser	Staff Scientist	Sherwin-Williams Company
Timothy	Hebrink	Staff Scientist	3M Company
David	Hungerford	Senior Scientist	California Energy Commission
Timothy	Hyer	Vice President of Digital	Gardner-Gibson
Jan	Kleissl	Professor	University of California, San Diego
David	Lamouranne	Captain	GreenStar Smart Roof
Ronnen	Levinson	Staff Scientist	LBNL Heat Island Group
Victoria	Ludwig	Heat Island Reduction Program Manager	U.S. Environmental Protection Agency
Robert	Martuch	Program Manager, Formulation Technology	Sherwin-Williams Company
James	Moses	Technical Services Manager	Mitsubishi Chemical Composites America
Tsutomu	Nagahama	Deputy General Manager	Dexerials Corporation
Hiroko	Furumi (Nakagawa)	Marketing Manager	Dexerials Corporation
Daisuke	Narumi	Professor	Yokohama National University
Olivier	Rosseler	Principal Scientist	Saint-Gobain
Gregory	Sarnecki	Senior Scientist	Behr Process
Erica	Sherman	Senior Research Associate	GAF
Michael	Shewmaker	Energy Specialist	California Energy Commission
Ginger (Jinzhen)	Shi	Section Manager, R&D	Behr Process Corporation
Ming	Shiao	Principal Scientist	GAF Materials Corporation
Morgan	Sibbald	Program Manager, Government Initiatives	Sherwin-Williams Company

Xiaochen	Tang	Postdoctoral Researcher	LBNL Heat Island Group
Peter	Turnbull	Principal, Zero Net Energy Program	Pacific Gas and Electric Company
Jerry (Jingting)	Wu	Applications Engineer	Dexerials Corporation
Jiachen	Zhang	PhD Candidate	USC

3 Remote participants

First Name	Last Name	Title	Organization
Craig	Tranby	Environmental specialist	Los Angeles Department of Water and Power
Dave	Sailor	Professor	Arizona State University
Martha	VanGeem	Principal Engineer	VanGeem Consulting
Howard	Wiig	Energy analyst	Hawaii State Energy Office
Gary	Ilalaole	Homeowner	NA
Scott	Kriner	Consultant	Metal Construction Association

4 Presentations, summaries, and notes

Key: Q = Question, A = Answer, D = Discussion

CW Benefits 1: Simulated HVAC energy savings in an isolated building (Task 2.1)
Ronnen Levinson, LBNL
9:15 – 10:00 am
(Link to presentation) (Link to 2-page summary)

Q: (Manufacturer) What was base case SR [solar reflectance] for building energy simulations?

A: (Ronnen Levinson, LBNL) 0.25 for walls, 0.10 for [residential] roofs.

Q: (Manufacturer) Why did you select these solar reflectances chosen for walls and the roof?

A: (Ronnen Levinson, LBNL) The cool-wall albedo for residential buildings assumed an off-white color, because most homes will not use bright-white walls. For residential roofs the increase from albedo 0.10 [base roof] to albedo 0.40 [cool roof] is actually greater than what Title 24 requires. These results can be scaled by albedo increase. It is easier to find cool options for walls than for asphalt shingle roofing.

Q: (Unknown) Is it easier to find and use cool wall products vs. cool-colored roofs for residences today?

A: (Ronnen Levinson, LBNL) Yes, it is easy to find white/off-white cool wall products today while cool-colored high-slope roofing products are less common.

Q: (Unknown) What is the size/dimension of the residential building prototype?

A: (Ronnen Levinson, LBNL) The single-family home has two floors with a total area of 220 m² (about 2,400 ft²). The apartment building has three floors with a total area of 2,010 m² (about 22,000 ft²).

Q: (Manufacturer) How do these [energy cost savings intensities] relate to energy cost savings for a household?

A: (Ronnen Levinson, LBNL) This slide reports annual energy cost savings per square meter of surface modified. You can multiply this value by the wall area to be made cool.

4.1 CW Benefits 2: Effect of neighboring cool walls on HVAC loads (Task 2.2)
Jan Kleissl, UCSD
10:00 – 10:15 am

(Link to presentation) (Link to 2-page summary)

Q: (Manufacturer) Did you take into account effective humidity?

A: (Jan Kleissl, UCSD) No, we did not but it's a good factor to consider.

Q: (Manufacturer) Is a 0.25 wall albedo for the base case a good value to use?

A: (Ronnen Levinson, LBNL) It is reasonable, and based on default values specified in the performance-compliance paths of building energy efficiency standards. Existing walls come in all different colors and albedos.

Q: (Manufacturer) Does the model take into account the convection changes?

A: (Jan Kleissl, UCSD) No we don't do fluids modeling. However, we factor in convection coefficients based on differences in surface/wall temperature versus air temperature.

Q: (Manufacturer) What do you assume is the building-to-building reflection interaction—diffuse or specular?

A: (Jan Kleissl, UCSD) Diffuse.

Q: (Manufacturer) This is still the result on the central building, right?

A: (Jan Kleissl, UCSD) Yes.

Q: (Christian Koehler, LBNL) Have you compared your results with Ronnen's SAF [solar availability factor] results? Do they match?

A: (Jan Kleissl, UCSD) The results from this modeling activity (Task 2.2) are generally lower than those reported in Task 2.1.

Q: (Manufacturer) How does the albedo of the street affect the model?

A: (Jan Kleissl, UCSD) Higher pavement albedo will generally enhance the effects. California neighborhoods usually consist of closely spaced buildings, with big roads (for cars), generally the view factor from wall to neighboring wall is much smaller than wall to pavement. Higher pavement albedo would enhance secondary reflections from neighboring cool wall to pavement to central building wall.

Q: (Manufacturer) Did you take into account all of the radiation exchanges between buildings, pavement, etc.?

A: (Jan Kleissl, UCSD) Yes.

Q: (Manufacturer) If you are an early adopter in Fullerton, let's say, and you get savings from your cool walls, then your neighbors decide they want cool walls too—are your savings reduced?

A: (Jan Kleissl, UCSD) It depends on how close your neighbors are, but generally yes.

Q: (Manufacturer) Have you calculated the savings based on distance between you and your neighbor?

A: (Jan Kleissl, UCSD) We used an inter-building spacing of 23 m = 70', which is a typical distance for a neighbor across the street in a residential neighborhood. SAFs [solar availability factors] in Ronnen's presentation can be used to analyze the effects of building spacing.

A: (Ronnen Levinson, LBNL) No matter what distance we choose, we'll be wrong—people must do this kind of modeling for their specific building.

Q: (Manufacturer) You didn't talk about factoring in emissivity.

A: (Ronnen Levinson, LBNL) We assume a thermal emissivity of 0.90, which is pretty accurate so long as the material does not have a bare metal surface.

Q: (Manufacturer) What about the reduction of community wide air temperature from deploying cool walls?

A: (Ronnen Levinson, LBNL) This will be presented during an upcoming presentation (Task 3.2).

Q: (Manufacturer) If I park my car next to a cool house—does my car warm up?

A: (Jan Kleissl, UCSD) Depends on orientation, time of day, and climate but it could.

Q: (Bill Dean, CalEPA) Does the TUF-IOBES model take into account light that reflects off the wall to the ground, etc?

A: (Ronnen Levinson, LBNL) Yes.

4.2 Morning discussion section
Facilitated by Ronnen Levinson and Haley Gilbert, LBNL
10:15 – 10:40 am

D: (Manufacturer) For cool walls there doesn't have to be a cost increase. Therefore, it becomes more of a marketing dilemma to convince the consumer that light-colored walls are also "cool" to have.

D: (Manufacturer) If you do a survey of wall products on the market, 60-70% of products are already light colors. Therefore, the projected benefit of this work would be smaller since you are only improving the remaining 30-40%, right? Also, color choice is important. If we tell people to change from a nice dark cedar siding to white cedar siding in order to save 5% on energy. That value is not enough to convince consumers, so we need to remember to respect color.

Q: (Manufacturer) Is there an inherent cost premium associated with cool pigments? Is the cost something where if you scale-up the manufacturing of the product, the pigments costs can decrease?

A: (Manufacturer) With these things we first need to start small and see how amenable people are to adopting them. We also need to introduce incentives to help drive the market in this direction.

A: (Manufacturer) I can provide a commercial viewpoint. One of the problems with life cycle cost analysis (LCCA) is that the people who construct the building are never the same as those who operate it. So the life cycle costs occur to different people at different stages. We see this again and again where studies are done but things never get adopted. The builder has a responsibility to be economical, and so anything new is going to be a hard sell if it is based on any type of increased [up-front] cost. All manufacturers have gone through these LCCA tools and found that it has very little impact on the actual construction of the structure.

Q: (Ronnen Levinson, LBNL) What is the actual cost [of cool pigments]?

A: (Manufacturer) It's about three times the cost versus conventional [pigments], generally speaking.

Q: (Ronnen Levinson, LBNL) What fraction of the coating is pigment?

A: (Manufacturer) Depends on the tone [of the color]—for a deep brown it might be 7-18%.

A: (Ronnen Levinson, LBNL) In roofing the specialty pigments are in the ballpark of 10% or so of the total [material] cost. So if 90% of the coating cost relates to other things, a 3X pigment cost increase is not actually as much as it initially sounds.

D: (Manufacturer) Don't forget that the biggest cost difference has to do with the painting application. You can have inefficient and efficient methods and everything in between. So if

you have an efficient coating system (like coil coating), the cost difference will be very different from an inefficient method (like powder coating).

Q: (Manufacturer) I would think it is easier to adopt light-colored walls. Where do you think the market is going now? Let's say that if people are trending towards light colors; then doesn't that mean cool dark pigments represent going in a different direction?

A: (Manufacturer) Yes, most exterior wall coatings [currently] are light colors.

A: (Manufacturer) In Europe, brighter deeper colors are actually pretty common but still the vast majority are light colors.

Q: (Unknown) So does this mean that we don't need special pigment technology since light colors are already popular?

Q: (Bill Dean, CalEPA) In California, can we make [cool wall] regulations and still offer the same color range [customers find today]?

A: (Manufacturer) We would need to know what the required SR would be.

A: (Ronnen Levinson, LBNL) Let's say 60%.

A: (Manufacturer) We also need to know about longevity requirements and durability too.

4.3 CW Co-Benefits 1: Pedestrian mean radiant temperature and thermal comfort (Task 3.1)
Jan Kleissl, UCSD
11:00 – 11:30 am

(Link to presentation) (Link to 2-page summary)

Q: (Manufacturer) What about the aspect ratio/view factor?

A: (Jan Kleissl, UCSD) Not much effect—there is 0.5 view factor with a multi-family residence.

Q: (Manufacturer) What about the interaction with ground albedo?

A: (Jan Kleissl, UCSD) In these simulations, we assume ground albedo of 0.10.

A: (Ronnen Levinson, LBNL) If I make a wall more reflective it lowers the wall's temperature. More sunlight is reflected from the wall, but the wall is cooler and emits less thermal radiation. It's not an equal balance, though; the decrease in emitted longwave radiation is not as great as the increase in reflected sunlight. As the pedestrian becomes more reflective, the effect [of raising wall albedo on pedestrian comfort] decreases.

Q: (Victoria Ludwig, EPA) Have you looked at internal thermal comfort [that inside unconditioned buildings]?

A: (Jan Kleissl, UCSD) We will be looking at that soon. We are currently running simulations. It'll be interesting to look at what happens in indoor environments where you don't have air conditioning.

Q: (Manufacturer) How do the effects presented here compare to heat island effects [in magnitude]?

A: (Ronnen Levinson, LBNL) Wait for George's presentation (Task 3.2) coming up next.

Q: (Manufacturer) Do you account for high performance technologies in windows? I expect the answer is no, but will you eventually incorporate things like 3M's IR reflective window film?

A: (Jan Kleissl, UCSD) We haven't done it but you can get applicable results by changing the reflectance, and emission inputs accordingly.

A: (Ronnen Levinson, LBNL) If interested, I can introduce you to Christian Kohler of the Windows and Daylighting Group.

4.4 CW Co-Benefits 2: Urban climate impacts of cool walls (Task 3.2)
George Ban-Weiss, USC
11:30 am – 12:00 pm
(Link to presentation)

Q: (Manufacturer) What is the albedo of rooftop PV?

A: (George Ban-Weiss, USC) There is an "effective albedo" of 0.40 albedo from an efficient PV system which is similar in albedo to cool-colored roofing products.

Q: (Unknown) If you made all buildings in a city with cool walls and cool roofs—how much change could you expect?

A: (George Ban-Weiss, USC) Depends on albedo increase, but if you're looking at peak temperature reductions, I would say a ballpark value of peak canyon air temperature reduction is 1˚ C. Note that you can't scale based on spatial adoption though you can scale by albedo increase.

Q: (Unknown) What is the impact of June gloom on the calculations?

A: (George Ban-Weiss, USC) If you don't know, this is a phenomenon where in June the waters off the shore are cold and the land is warmer; therefore, a marine layer forms in June. You can look at results on mostly cloudy days though to get the answer, and I would expect to see smaller reductions on those days.

Q: (Manufacturer) So how does all of this affect air pollution—ozone in particular?

A: (George Ban-Weiss, USC) I defer to Jiachen's presentation (Task 3.3) later today, and also note that the full research on this topic isn't yet completed. But if I were a betting man I

would think that ozone will decrease since the temperature effect will outweigh the dispersion effect of slowing down the removal of ozone.

Q: (Manufacturer) But isn't there another study that talks about increase in ozone from an increase UV reflectance?

A: (George Ban-Weiss, USC) I am a co-author on that paper. Note that in these simulations [those in the current study] we assume UV reflectance remains unchanged in the cool roof and cool wall scenarios.

Q: (Ronnen Levinson, LBNL) So you mentioned that there's less sunlight on walls than on roofs—about half—is it right to say that we see these cool wall temperature reductions because there are more walls than roofs?

A: (George Ban-Weiss, USC) It's two things: 1) canyon air temperature—if you increase wall albedo, which is much closer to the urban canyon than roofs are, you can imagine that changing walls has a much larger relative impact than changing roofs; and 2) yes you are right there is more wall area than roof area.

Q: (Manufacturer) Cooling the land reduces sea breeze—does this model take this effect into account [the reduced sea breeze]?

A: (George Ban-Weiss, USC) Yes. We note that sea breeze dampens the effect of cool walls, but doesn't completely eliminate the effect.

Q: (Manufacturer) Can you relate the magnitude of your results with the magnitude of Jan's results? I'm speaking in a thermal comfort sense. It seems negligible.

A: (George Ban-Weiss, USC) So it's difficult to compare—scale is one of the differences between our research. I am looking at the spatial scale dependence of cool wall adoption while Jan is looking at neighborhood scale. I am looking at a megacity so there is an important accumulation effect [that you don't really see at a smaller scale]. Because of the spatial scale effects like this you can't really scale linearly between our models. From a thermal comfort point of view maybe you won't see much effect, but from an urban heat island mitigation viewpoint these numbers are not negligible.

Q: (Ronnen Levinson, LBNL) Can you compare these reductions with expected summer average temperature increase due to climate change?

A: (George Ban-Weiss, USC) Those projections are on the order of 4 °C; these reductions are on the order of a tenth of that. [Cool surfaces] will not reverse effects of climate change, but it's not negligible. Also, I will mention here that I did a study a while ago on this topic but for cool roofs in Los Angeles. For the mid-century results, cool roofs can partially reverse climate change in residential areas and in industrial areas it can almost fully reverse it since you can have very high albedos on horizontal roofs. But by the end of the century, climate change dominates. Therefore, it's more like a near-term solution but certainly not a long-term answer to climate change.

Q: (Haley Gilbert, LBNL) Did you evaluate temperature reductions on extreme heat days currently and under future climate change scenarios?

A: (George Ban-Weiss, USC) Baseline meteorology affects extreme heat days. On a hot day you see lots of stagnation, which would probably be similar on an extreme heat day, though not exactly the same. Jiachen's simulation data actually includes an extreme heat period and we can look at those three days compared to what we see in the whole month. But talking in terms of predicting future events we need to know things like how climate change affects wind speed which is not well known right now. And that is why research into how climate change affects air pollution is super uncertain.

Q: (Manufacturer) Can cool wall reductions in greenhouse gases impact the temperatures of Los Angeles?

A: (George Ban-Weiss, USC) Only by a tiny amount, and we don't include these effects in our modeling. You could reduce greenhouse gases in Los Angeles to zero and it wouldn't really affect the climate of Los Angeles. This is because climate change is a global phenomenon. If everyone had electric cars in Los Angeles, you still wouldn't see much difference! Basically, it is not local.

Q: (Manufacturer) What about PV panels on rooftops?

A: (George Ban-Weiss, USC) This relates to my previous study looking at effects of cool roofs on climate change. If a PV cell is 10% reflective and let's assume that conversion efficiency is the upper end of what is achievable like 30%, then you could say the effective albedo is 40% and that's roughly equal to a high-performance cool-color residential roof. Therefore, the same cooling benefits apply here. You can use effective albedo as a way to look at how PVs will affect climate. So if we say that efficiency was 20% and that the effective albedo is 30%, then you can say the PV has albedo equivalent to cool-colored residential roofs. But neither will be as good as a white commercial cool roof.

A: (Ronnen Levinson, LBNL) Of the sunlight that arrives on the surface of a PV panel, some gets reflected, some is converted, and some is absorbed. The fraction gets absorbed without conversion is what matters. Air flow under roofing tiles or PV panels does affect the extent to which the building heats up but doesn't affect the urban system.

Q: (Bill Dean, CalEPA) Regarding semi-volatiles in gas vs particle phase—if I breathe them in, what are the differences when it comes to health effects?

A: (George Ban-Weiss, USC) The accumulation mode particles are the ones that persist in the atmosphere the most. Size is 100 - 1000 nm. Due to the size, they don't deposit very quickly. When you breathe gas it diffuses quickly and it would be taken up in the nasopharyngeal area. Same as really small particles. The semivolatiles are usually in accumulation mode, so too big to diffuse quickly and too small to settle by gravity, so they make it deeper into airways, so then can translocate into different parts of the body. Therefore, where the pollution deposits in the body matters for health reasons.

Q: (Manufacturer) Anybody studying energy storage at nighttime?

A: (Paul Berdahl, LBNL) Short answer is no—there's a common strategy of nighttime ventilation and you can use that to store energy temporarily but I don't think there is any widespread systems examination that's going on. In its simplest form, you just open your windows at night, then close up the house during the heat of the day. There are also strategies where nighttime cold water is produced by radiative cooling panels, or by refrigeration, and circulated to produce cooling during the day. Commenting on PVs—it's great that you can have a reduced heat load because you're converting solar energy to electricity. In a building consider though that the electricity is being used to power appliances and that heat will go back into the environment. This is in comparison to the cool roof where the roof has an advantage as it just reflects back into space and also cools the interior space.

Q: (Manufacturer) Los Angeles was the basis for this study, how do you extrapolate to Phoenix or some other city?

A: (George Ban-Weiss, USC) You can't—the temperature impacts of increasing albedo don't really translate from one city to another unfortunately so things like differences in baseline temperature, wind speed especially, evolution of boundary layer mixing heights. You can make rough extrapolations but I would hesitate to extrapolate results to another city. You can instead run the simulations in another city and then see how they differ.

D: (Victoria Ludwig, USEPA) The discussion questions on the back of the paper you gave us, align with the trouble we run into with cities as well. Like how these results would be received by cities. Cities would need someone to translate this research into laymen's terms and we do try to do this but it's hard. Local officials come to me and say well I can't implement all mitigation strategies, and I can't do cool roofs alongside cool walls and vegetation—so which one do I do? If I want to do cool walls, well then what policy incentives would work for the non-municipal buildings which the city doesn't have direct control over. The officials will ask me who has studied this and how can they communicate results to their elected officials. They would also want to know what other cities are implementing these strategies and to what success. This type of information would be very helpful for me.

4.5 Overview of California's Electric Program Investment Charge (EPIC)
David Hungerford, CEC
12:40 – 1:00 pm
(Link to presentation)

Q: (Manufacturer) Is there a limit on percent renewable energy for the grid to manage?

A: (David Hungerford, CEC) I'm not qualified to answer that. The general answer would be yes, but we don't know what that is. I've read recent estimates that put it at a very high number. It depends on what you want the system to look like. We started 120 years ago and up until the [19]70s had a grid design that said load should be met by supply and it was all about how to build supply to meet the load and also keep stability. System operations, utilities,

transmission organizations functioned like they are an accelerator with no brake pedal. That was their goal. If we instead have a system where power is available sometimes and less available at other times, or less available in a low carbon sense, at that point consumption is going to have to shift. If we keep consumption at current levels and try to store renewable energy, well that would be expensive. But how do you match the consumption behavior to the available load—that's the question. If everyone was willing to live that way [because some people do live off the grid] then we'd have no problem. So it's a matter of willingness to adapt. How much can you do without having to change behavior? Well that's going to be a lower number.

4.6 CW Technologies 1: Natural exposure of wall products (Task 4.1)
Hugo Destaillats, LBNL
1:30 – 2:00 pm
(Link to presentation) (Link to 2-page summary)

Q: (Manufacturer) When you did your measurements, what's the spot size that you measure, and is it large enough to capture the differences in soiling?

A: (Hugo Destaillats, LBNL) 1" spots and three spots per specimen. So yes.

Q: (Unknown) Do you discriminate between microbial growth and soiling?

A: (Hugo Destaillats, LBNL) We don't analyze what's on the surface, only the effect whatever is on the surface has on the solar reflectance. I would say in humid areas the soiling would probably be more microbial related, depending on the specific products we're talking about [especially for porous clay tiles, you may not see it on other types of materials].

Q: (Manufacturer) What is the resolution of the images? Can you see soiling particles in these photographs?

A: (Sharon Chen, LBNL) I don't know; we just use a point-and-shoot camera.

Q: (Manufacturer) Have you measured how hot the samples get?

A: (Hugo Destaillats, LBNL) No, we haven't measured that. But we could.

Q: (Manufacturer) Did you measure color L, a, b?

A: (Hugo Destaillats, LBNL) We will eventually do so for some products using spectrometer measurements.

Q: (Manufacturer) Why do you report solar reflectance instead of temperature under the sun?

A: (Hugo Destaillats, LBNL) We only report solar reflectance, since temperature will ultimately be affected by other factors [like wind].

Q: (Manufacturer) There are a number of industry standards for durability and longevity of paint. What are the durability ratings for these products?

A: (Hugo Destaillats, LBNL) We don't know. The manufacturers will know, but the products in this set that are commercial will probably have passed those tests but we won't know unless the manufacturers tell us more about these products.

D: (Manufacturer) Testing those parameters would be a very important step for acceptance in the coating industry.

Q: (Manufacturer) When you made the reflectance measurements after soiling, did you wash and return [specimens] to the racks?

A: (Hugo Destaillats, LBNL) No.

4.7 CW Technologies 2: Self-cleaning and de-polluting photocatalytic materials (Tasks 4.2 and 3.3) Xiaochen Tang, LBNL and Jiachen Zhang, USC 2:00 – 2:30 pm

(Link to presentation) (Link to 2-page summary)

Q: (Manufacturer) The cool roofing model shows an increase in pollution, why?

A: (Jiachen Zhang, USC) The increase in particulate matter (PM) concentration is reported in the modeling work of Epstein et al., (2017). They suggested that cool roofs will reduce temperatures and lower planetary boundary layer (PBL) height, and thus suppress pollutant dispersion. [See http://www.pnas.org/content/114/34/8991.abstract]

A: (Haley Gilbert, LBNL) Let me remind the group that these effects are site-specific, and slight differences from site to site may affect which one of the pathways dominates, leading to either an increase or decrease in pollution.

Q: (Manufacturer) You're looking at NO_x deposition and the ability to "react that away" and also how that affects ozone and PM. Are you thinking at all about what other things in the air might be affecting these reaction sites?

A: (Hugo Destaillats, LBNL) The catalysts are on the surface and will react with whatever is there. Let's say the coating formulation is inert and physically covered by a soiling layer—then the reaction is totally blocked. You saw in the dry season the NO_x removal decreased and later increased when it was cleaned. This represents a physical barrier preventing the reaction from occurring.

Q: (Manufacturer) I was wondering specifically about VOCs or other things in the air that could be competing for those sites on the surface as well.

A: (Hugo Destaillats, LBNL) We can look at concentration and reactivity. NO_x is pretty reactive, and there's a lot of it. But you're right so I'll emphasize here that this is a test that is done to characterize the material and not to predict how it will react in the environment.

4.8 CW Technologies 3: Fluorescent cool pigments (Task 5.1)
Paul Berdahl, LBNL
2:30 – 3:00 pm
([Link to presentation]) ([Link to 2-page summary])

Q: (Unknown) Did you run six identical samples to test whether the [ESR measurement] apparatus worked?

A: (Paul Berdahl, LBNL) Yes.

Q: (Manufacturer) Do you check the emissivity of the samples?

A: (Paul Berdahl, LBNL) Yes, we did. We also checked the apparatus results by running with thermistors. For the crystals the thermal emissivity was a bit low, so we coated the sample with a transparent acrylic layer to bring it up to 0.90.

Q: (Manufacturer) What was the substrate with the rubies? I wasn't clear what you were putting the ruby over.

A: (Paul Berdahl, LBNL) We put the pigment into a clear base. We have a standard white substrate that is an aluminum panel with 3 coats of brushed white. If you use a black substrate you get a factor of 17 less performance. You need a good white substrate.

4.9 CW Technologies 4: Retroreflective materials (Task 5.2)
Ronnen Levinson, LBNL
3:40 – 4:00 pm
([Link to presentation]) ([Link to 2-page summary])

D: (Unknown) In residential construction, lap siding already has an upward tilt so that geometry could be accommodating to the retroreflector geometry you propose.

Q: (Unknown) Did you measure retroreflection with different sun angles?

A: (Ronnen Levinson, LBNL) The measurements performed by Dexerials included various incidence angles. They illuminated the samples at varying incidence angles and the detector moves around to detect retroreflection.

Q: (Manufacturer) Did you give any thought to flecks in the paint? Metallic flakes, mica flakes?

A: (Ronnen Levinson, LBNL) Not sure how they can be used for retroreflection.

D: (Manufacturer) In a coating they tend to be used all facing one angle

D: (Ronnen Levinson, LBNL) Let's talk about this afterwards.

4.10 Advancing cool wall adoption through standards, incentive programs, and application guidelines (Task 6.1)
Haley Gilbert, LBNL and Ronnen Levinson, LBNL
4:00 – 4:30 pm
(Link to presentation) (Link to 2-page summary)

Q: (Manufacturer) With a wall we have multiple products: windows from one company and shutters from another; one side of house has a stone wall but the other side is something else. So how do we write building code language for a cool wall when there's so much going on?

A: (Ronnen Levinson, LBNL) For us, "wall" just means net wall—no windows, no doors. Anything that's a shutter is not in the purview of this. We care about SR and TE, much as we do for roofs. There are lots of different types of wall materials, but you set requirements independently of the materials. Maybe you can have different requirements based on wall direction just like there are different requirements based on roof slope.

A: (Jan Kleissl, UCSD) Maybe we could do something like have standards incorporating area-weighting of reflectance.

Q: (Manufacturer) With regards to the amount of work to get to those requirements, some of the legwork has already been done with roofs so do you think the process will be as long as with roofs?

A: (Haley Gilbert, LBNL) I think it may be shortened but success will depend on the level of interest.

D: (Manufacturer) You can look at roof/attic systems as a monolithic structure. For the residential wall market, it's similar, where there's wall and windows and you can generalize what % of the surface is wall or window. But when you're looking at a commercial product, there is more variety. You can't just expect that you can approximate these exterior surfaces as just X% walls and X% windows. You have great variety of construction, for example storefronts, curtain walls, etc., where there's a lesser percentage of wall vs. other parts. Let's say in a storefront 25% of the surface is wall, and now I've just made it cooler! In the real world this doesn't really mean much [because the cool wall makes up a small fraction of the storefront]. My thought on this is that you need to break down your timeline of adoption between the residential sector where I think there's a good chance of adoption and the commercial sector where I think it would be much harder to get support for a variety of reasons.

D: (Code consultant) In ASHRAE 90.1 what we did, as you recall in the very beginning with Ronnen's presentation, is to separate things by building type. There are already some commercial prototypes that have a low wall-to-window ratio so because the analyses here have accounted for that, I don't think it's a lost cause to do cool walls in the commercial realm. Also, I want to mention here that Climate Zone 0 encompasses a band including central South America, Africa, Indonesia, etc., and while none of these areas happen to be in U.S. they include major population centers. I want to add that I know solar reflective index (SRI) is for horizontal surfaces but we used it because it is referenced in LEED, however we can definitely go back to solar reflectance.

D: (Utility) I think we need some real-world field measurements [as we did for cool roofs]. We don't really know what's going to happen in the field so impacts should be validated by field measurements.

Q: (Ronnen Levinson, LBNL) Could this be funded by the next three-year phase of the EPIC program?

A: (David Hungerford, CEC) The initiatives have not been written yet. And so certainly funding is a possibility.

D: (Haley Gilbert, LBNL) It is tricky to do field work with these new technologies. It's hard to tease out the impact of a specific technology when in the field you see a combination of all these different technologies put together. So you need is isolated studies that can be easily controlled.

D: (David Hungerford, CEC) There are categories of research that deal with demonstration and development. What you're talking about falls more under applied research. Within a longer-term project or larger proposal there could be a component of applied research alongside a demonstration effort.

D: (Manufacturer) I want to offer a word of caution. You've touched on the fact that wall geometry is more complicated than a roof with effects from other surfaces. It just seems so difficult to come up with a simple narrative you can tell a consumer about what sort of benefit they can see. If a given magnitude of benefit is so dependent on specific conditions, what if they come back to us as manufacturers and say, "Well we didn't see the benefit you claimed!". What we sell is a base paint. That base paint can then be tinted as the customer pleases at our various locations. So we test the base paint and report the results. But ultimately the customer can come in and add color tints to it in the store.

D: (Unknown) Also remember that with these cool colors you need to be careful about mixing different incompatible kinds of pigment! It can drop the SR!

D: (Manufacturer) I'll tell you I didn't hear anything about the cost part of the equation today. The cost is a big factor in whether something will be adopted. A method towards adoption with existing products [that have no cost premium] might be moving towards white walls.

But home owner associations might not like this limited choice/color. Until the cost issue is sorted out I don't see a clear path towards adoption.

D: (Ronnen Levinson, LBNL) Spectrally selective pigments may be three times the cost, but that is for the pigment only right? If the pigment represents only, let's say, 10% of the cost, then that "three times" figure [offered by the Ultimate Coatings rep] doesn't necessarily represent the total cost increase of incorporating cool pigments.

D: (Manufacturer) If we talk about conservative adoption with realistic [SR] numbers, and do not include the realm of "Martha Stewart great vibrant colors great prices"—we're talking about modest colors and then I think we can definitely keep costs in line.

D: (Manufacturer) I want to remind everyone that when GAF cool roof shingles first came out they were very expensive. But then now everyone makes them and the prices have gone down a lot. So we have to recognize that there is an educational curve here in the industry too. My background is in the trades, and I can tell you that the cost of labor is the preponderance of the cost of an installed roof/wall. We get stuck in this conversation about cool walls being so expensive, but [the magnitude of] that cost doesn't even touch the labor cost.

D: (Unknown) So let's say that we're not considering cool pigments—let's talk about white pigments. Can we use white paint as the cool wall case?

D: (Manufacturer) Look, consumers are paying extra for energy-saving products. Therefore, manufacturers need compelling energy savings information to share with consumers. However, if we sell a cool roof, the manufacturer has to substantiate the energy savings claim—well if you buy this you can save this much. Manufacturers are liable in a legal sense for the claims we make. [Lots of agreement from attendees.] So we are looking for whatever support this group can offer us in terms of demonstrating concrete benefits.

D: (Manufacturer) When I buy a roof, I don't paint it—I buy some roofing material that was already painted. I don't know what it cost manufacturers to produce the cool product, I just buy the complete product. On the other hand, a large percentage of walls in the residential sector are painted in the field by somebody who went to a big box store and bought a 5-gallon bucket of paint to paint a house. So the owner's going to know what the cost is—that is the cost of that bucket of paint. The labor is going to be exactly the same for painting houses, so you don't get the benefit from efficiencies in painting [application]. What it costs to get that paint will be what is important to the owner. In the commercial sector, the cladding comes pre-finished so any cost increases can be absorbed into the cost of the product, which may be a bit more.

D: (Manufacturer) I think the three-year aged value is very important. With this value, you can see there is a real difference between all these options. I like to tell people that all white paints are not created equal. If you go to the Cool Roof Rating Council (CRRC) website you can see how different the three-year aged values are for the different [white] products. So

you can sell high-end premium paint and point to the aged values to show how it doesn't soil as quickly. The aged cool wall SR values will be helpful to know and share.

D: (Manufacturer) Color is very personal. Don't mess with the color space of your offerings. Whatever new technology that is introduced needs to be able to accommodate all the color choices that people want. It doesn't matter if the customer is only buying one of your products, they want to see that they have hundreds of options to choose from. It doesn't matter if you don't like [this particular shade of brown]; there is a customer out there that really does want [the particular shade of brown]. I don't want to introduce cool walls here if that is something that will limit the color space of what we sell.

D: (Ronnen Levinson, LBNL) Well we only intend to try this in areas where it's beneficial.

D: (Manufacturer) Look you have to understand that where California goes, so goes the nation. [Lots of agreement from audience.] So if you're really going to be that restrictive, know that it will affect the national market.

D: (Ronnen Levinson, LBNL) In cool roofing, the codes are climate zone specific.

D: (Manufacturer) All the large paint companies will sell paint that says Title 24 compliant no matter where you are. It's just not cost-effective for manufacturers to sell different products based on geography.

D: (Manufacturer) Look, codes are political documents. And those political entities don't always align with your climate zones. So if cool walls are adopted into building codes and they become prescriptive, know that it's going to end up being enforced on someone who doesn't need it.

D: (Haley Gilbert, LBNL) One way to address that is to tailor the language so that it's not an imposition, but more like an option. Or incentivize, rather than prescribe.

D: (Manufacturer) Providing incentives is basically giving someone something for nothing. That's what I like about white walls as a pathway of adoption. It's easy to find in the market and already used. Once it's accepted, maybe then you start adding things like cool colors.

D: (Manufacturer) I just wanted to add that in terms of starting small, I don't think I would go adding on all these extra technologies like self-cleaning, retroreflectors, or fluorescence right at the very beginning.

D: (Manufacturer) There are lots of things premium paints do that consumers don't know about. We match our standards to the Master Painter's Institute, which has standards about washability, etc. But as a consumer you have no idea. We could do something like that with cool walls. It doesn't go on the label, but it will be inherent. You can accomplish this working with those organizations to get these standards in, working with general contractors saying well you have to use paints that have these characteristics.

Q: (Manufacturer) Have you looked at what Europe is doing when it comes to energy efficiency?

A: (Haley Gilbert, LBNL) With regards to cool walls/roofs research, the UK building stock is older and lacks cooling systems. So they are evaluating cool walls/roofs as a way to mitigate future climate change warming effects since they don't have infrastructure like air conditioning and people are not acclimated to hot weather.

Post workshop feedback (via email)

Code consultant:

Consider the point of entry: in most regions of the country, walls are not painted, even residential walls. Brick, stone, or Hardie board [fiber-cement siding] are used. If the point of entry could allow a range of preferable color choices in products that manufacturers already have, this would be best. However, I realize that the analysis was done for 0.6 [solar reflectance] which is very white.

A map of world climate zones is shown in Figure Annex1-3, on page 379 of ASHRAE 90.1-2016. There are also tables in Annex1-3 that list international cities in various climate zones. It might be that half of the world population lives in climate zones 0 and 1.

Howard Wiig, Hawaii State Energy Office:

Martha asked question regarding color selection. Each paint company has color blades of seven colors each. When I selected the lightest two, the lowest common denominator was 0.64—hence my number. Very scientific.

The addition of a white primer or underlayment increases reflective efficacy by 17 times? If so, that should be the primer of choice—can be inexpensive acrylic as it won't weather and acrylic has good adherence properties. [Note from Ronnen: the 17X increase mentioned by Paul Berdahl referred specifically to the performance of *fluorescent* cool pigments.]

I tuned in late, but I didn't hear mention of Stanford (maybe that explains it) studies in reflective wavelengths exiting the atmosphere, presumably unhindered by atmospheric elements.

The fact that reduced reflectance potential of walls is practically offset by walls occupying more space than windows.

Thanks so much for giving Hawaii full billing! The photos you showed were Laie Elementary school. I will check to see if good monitoring was done.

I spoke with Energy Star regarding their minimum roof reflectance values. They admitted that they hadn't paid much attention to this element. I and others agree that the new minimum should be 0.80 initial solar reflectance and 0.65 aged—and that's conservative.

I agree with Martha that commercial roofs like warehouses and Big Boxes are excellent candidates for cool walls.

The [building simulation] results showed that in Climate Zones 1-3, cool walls have excellent performance and payback time (if, indeed, there's a cost premium for cool walls.)

Manufacturer:

When we talk about co-benefits of cool walls, I am also thinking about extended product durability. Lowering the wall temperature will slow down the degradation kinetics (typically increasing the temperature by 10 ˚C doubles the reaction rate). This would have a positive impact on cost as coatings or cladding materials would require less maintenance.

Similarly, reducing the heat build would enable more cladding options in warm climates. Vinyl and polypropylene siding cannot be used in warm climates as they soften with too much heat (around 150-170 ˚F for vinyl if I remember correctly).

Occupant comfort is another added benefit (although more difficult to quantify and market). We have a team in France dedicated to occupant comfort and quantifying it. Maybe we can involve them at some point.

I will present the photocatalytic work to the business units and discuss publishing the results.