E-21. Install Cool Pavement

GHG Mitigation Potential

Potentially small reduction in GHG emissions from energy demand

Co-Benefits (icon key on pg. 34)

Climate Resilience

Cool pavement absorbs less heat, reducing the urban heat island effect and building both individual and community-wide resilience to high temperatures.

Health and Equity Considerations

Cool pavements should be prioritized in vulnerable and sensitive communities that experience urban heat island effects, have large amounts of paved areas, and lack sufficient shade. Any disbenefits from cool pavement installation projects such as glare should be addressed during the project's planning phase.

Measure Description

This measure involves installing cool pavement in place of dark pavement. Cool pavement helps to lower ambient outdoor air temperatures when compared to dark-colored, heat-absorbent pavement such as asphalt. This reduces the electricity needed to provide cooling, thereby reducing associated GHG emissions, depending on the project parameters (e.g., climate, carbon intensity of local utility).

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

This measure is only applicable in areas where research is available on the energy savings from cool pavement (see GHG Calculation Variables). Implementation of this measure may result in limited or no GHG reductions for highly developed areas with tall buildings or in urban canyons, such as in a downtown or commercial area, or areas with extensive tree canopy cover. Tall buildings and tree canopies restrict the amount of sunlight reaching the street surface, and thus limited additional cooling would be achieved by the pavement surface.

Furthermore, installing cool pavements in areas with tall buildings or in urban canyons may result in an increased heating demand during the cooler months. Cool pavement installation should be prioritized in paved areas in open spaces with high urban heat island effects, such as major freeways, highways, arterial roads, and parking lots (Altostratus Inc. 2020).

Cost Considerations

The cost of applying cool pavement versus conventional paving materials will vary by region, contractor, time of year, materials chosen, accessibility of the site, local availability of materials, underlying soils, size of the project, traffic conditions, and desired lifetime of the pavement.

Expanded Mitigation Options

Pair with Measures C-1-A , *Use Electric or Hybrid Powered Equipment*, C-1-B, *Use Cleaner-Fuel Equipment*, and C-2, *Limit Heavy-Duty Diesel Vehicle Idling*¸ to ensure that the construction equipment used during the installation of cool pavement use less fuel, thereby further reducing GHG emissions.

GHG Reduction Formula

$$A_C = -\left(\frac{B_c \times D}{E}\right) \times J$$

$$K_H = \left(\frac{B_H \times I}{E}\right) \times M$$

$$L = \left(\frac{((A_c \times F) + (K_H \times G))}{N}\right)$$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	Reduction in electricity demand from the installation of cool pavement	[ ]	MWh/year	calculated
K	Increase in natural gas demand from the installation of cool pavement	[ ]	MMBtu/year	calculated
L	GHG emission reductions from the installation of cool pavement	[ ]	MT CO_2e/year	calculated
User Inputs				
B	Amount of cool pavement that is being constructed	[ ]	ft^2	user input
Constants, Assumptions, and Available Defaults				
C	Electricity Demand Forecast Zone – electric component (Zones 4, 5, 7, 11, 12 ,16, 17 or 18)	Figure E-1.1 Table E-1.1	integer	CEC 2017
H	Electricity Demand Forecast Zone – natural gas component (Zones 5 or 16)	Figure E-1.1 Table E-1.1	integer	CEC 2017
D	Cool pavement maximum energy saving per year	Table E-21.1	kWh/year/m^2	Lawrence Berkely National Laboratory 2017a, 2017b
E	Converting square feet to square meters	10.76	ft^2/m^2	conversion
F	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lbs CO_2e/MWh	CA Utilities 2021
G	Natural Gas Emission Factors	Table E-4.5	lbs CO_2e/MMBTu	U.S. EPA 2020
I	Cool pavement maximum heating savings per year	EDFZ 5 = -0.00829 EDFZ 16 = -0.0054	Therms/year/m^2	Lawrence Berkely National Laboratory 2017b

ID	Parameter	Value	Unit	Source
J	Converting kilowatt hours to megawatt hours	0.001	MWh/kWh	conversion
M	Converting therms to MMBTU	0.1	MMBTU/therms	conversion
N	Converting pounds to metric tons	2,204.62	lbs/MT	conversion

Further explanation of key variables:

- (B) – The amount of cool pavement that is being constructed.
- (C, H) – Climate zones are specific geographic areas of similar climatic characteristics, including temperature, weather, and other factors that affect building energy use. The CEC has specified numerous EDFZs in California, which are referenced in CEC's California Commercial End-Use Survey and Residential Appliance Saturation Study. This measure would only be applicable to certain EDFZs where research was done on calculating energy savings from the installation of cool pavement.
- (D) – The maximum electricity savings (kWh) per year per meter of installed cool pavement. This would only be applicable to eight EDFZs where electricity savings were quantified. The electricity savings and the EDFZs are provided in Table E-21.1.
- (F, G) – GHG intensity factors for major California utilities within the supported EDFZs are provided in Tables E-4.3 through E-4.5 in Appendix C. If the project study area is not serviced by a listed utility, or the user is able to provide a project-specific value (i.e., for the future year not referenced in the tables), users should use that specific value in the GHG calculation formula. If the utility is not known, users may elect to use the statewide grid average carbon intensity.
- (I) – The maximum additional heating requirements (therms) per year per meter of installed cool pavement. This would only be applicable to EDFZ 5 and EDFZ 16 because these areas were the only two included in the research paper that describes the additional heating requirement from cool pavement. For other areas, users could conservatively use the higher value from EDFZ 16 to estimate the additional heating requirement.

GHG Calculation Caps or Maximums

The maximum GHG emission reductions from this measure are tied to the total amount of area that cool pavement can be installed within a a supported EDFZ jurisdiction and the GHG intensity factors from the local utilities supporting that jurisdiction.

Example GHG Reduction Quantification

A city within EDFZ 16 is working on a pilot program that will install cool pavement on a 5-mile, 4-lane stretch of an arterial roadway. The total area of this roadway that would be covered is 1,267,200 square feet (BC, BH). Following the formulas above, this pilot program would result in a reduction of 3.27 $MTCO_2e$/yr in energy savings.

The following default values from tables in Appendix C are used.

- (D) – The cooling savings of 0.182 kWh/m^2/yr (Table E-21.1 in Appendix C) for EDFZ 16.
- (I) – The heating savings of -0.00554 therms/m^2/yr for EDFZ 16.

- (F) – The Los Angeles Department of Water & Power carbon intensity of electricity of 694 lbs CO_2e per MWh (EFEGHG) (Table E-4.3).

  (G) – The natural gas emission factor of 117.32 lbs CO_2e per MMBtu for residential uses (Table E-4.5).

$$A_C = -\left(\frac{1{,}267{,}200\ ft^2 \times 0.182\ kWh/m^2/yr}{10.76\ ft^2/m^2}\right) \times 0.001 MWh/kWH$$

$$A_C = -21.43\ MWh/yr$$

$$K_H = \left(\frac{1{,}267{,}200\ ft^2 \times 0.00554\ therms/m^2/yr}{10.76\ ft^2/m^2}\right) \times 0.1\ MMBtu/therms$$

$$K_H = 65.24\ MMBtu/yr$$

$$L = \left(\frac{((-21.43\ MWh/yr \times 694\ lbs\ CO_2e/MWh) + (65.24\ MMBtu/yr \times 117.32\ lbs\ CO_2e/MMBtu)}{2{,}204.62\ lbs/MT}\right)$$

$$L = -3.27\ MTCO_2e/yr$$

Quantified Co-Benefits

Energy and Fuel Savings

Successful implementation of this measure would achieve electricity savings due to the cooling effects of the pavement.

$$A_C = -\left(\frac{B_c \times D}{E}\right) \times J$$

Worsened Air Quality

While the measure would achieve electricity savings, it can increase natural gas consumption (K_H) during colder months and potentially worsen ambient air quality (U) from natural gas combustion.

Criteria Pollutant Emission Increase Formula

$$K_H = \left(\frac{B_H \times I}{E}\right) \times M$$

$$U = \left(\frac{(|K_H| \times G)}{X}\right)$$

Criteria Pollutant Emissions Increase Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
U	Increase in criteria pollutant emissions from building energy	[ ]	tons per year	calculated
User Inputs				

K	Increase in natural gas demand from the installation of cool pavement	[ ]	MMBtu/year	calculated
Constants, Assumptions, and Available Defaults				
H	Electricity Demand Forecast Zone – natural gas component (Zones 5 or 16)	Figure E-1.1 and Table E-1.1	integer	CEC 2017
G	Criteria pollutant emission factors of natural gas	Table E-4.5	lbs/MMBtu	U.S. EPA 1998
X	Converting pounds to short tons	2,000	lbs/tons	conversion

Further explanation of key variables:

- (K_H) – Because K_H is a negative value in the above equation, the absolute value is used to calculate the positive increase in criteria pollutant emissions.
- (G) – Natural gas GHG emission factors for residential and non-residential uses are found in Table E-4.5 in Appendix C. When choosing between residential or non-residential, it is recommended that users use the emission factor representing the most prominent land use near the cool pavement that is being constructed.

Sources

- Altostratus Inc. 2020. *Capital Region Heat Pollution Reduction: Atmospheric Modeling for the Development of a Regional Heat Pollution Reduction Plan*. February 26. Available: https://www.airquality.org/LandUseTransportation/Documents/Altostratus_Final_Report.pdf. Accessed: January 2023.
- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Lawrence Berkely National Laboratory. 2017a. *Are Cooler Surfaces a Cost-Effect Mitigation of Urban Heat Islands?*. April. Available: https://eta-publications.lbl.gov/sites/default/files/cooler_surfaces.pdf. Accessed: August 2023.
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- U.S. Environmental Protection Agency (U.S. EPA). 1998. *AP 42, Fifth Edition, Volume I. Chapter 1: External Combustion Sources. 1.4, Natural Gas Combustion*. July. Available: https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf. Accessed: January 2021
- U.S. Environmental Protection Agency (U.S. EPA). 2020. *Emission Factors for Greenhouse Gas Inventories*. March. Available: https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Accessed: March 2021