Cool Pavement Impacts on Climate Change

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Climate Resolve virtual Networking

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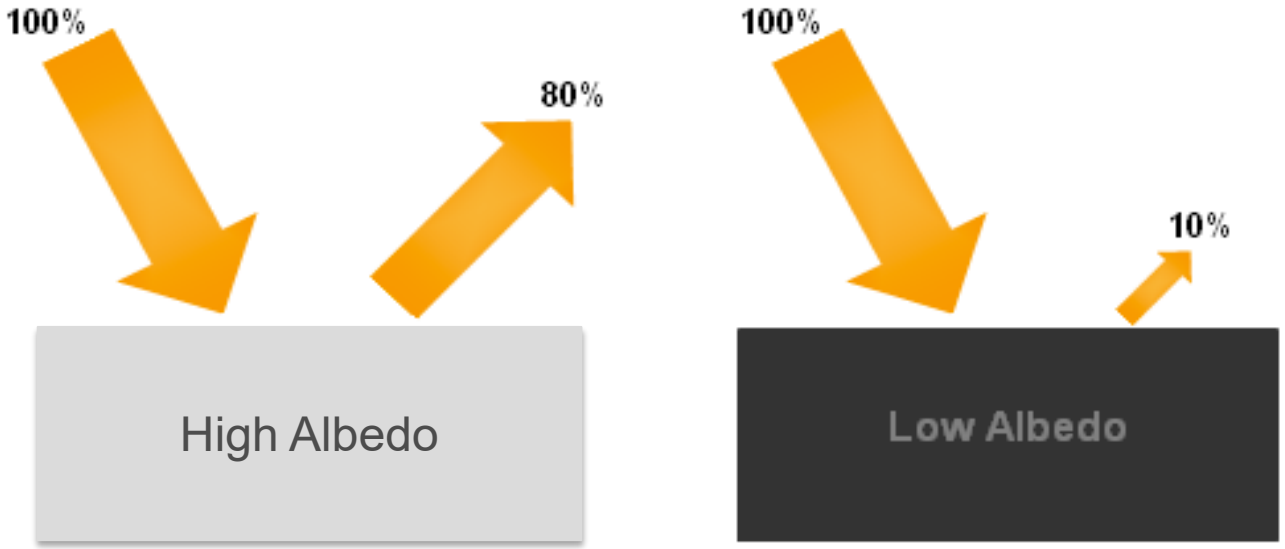
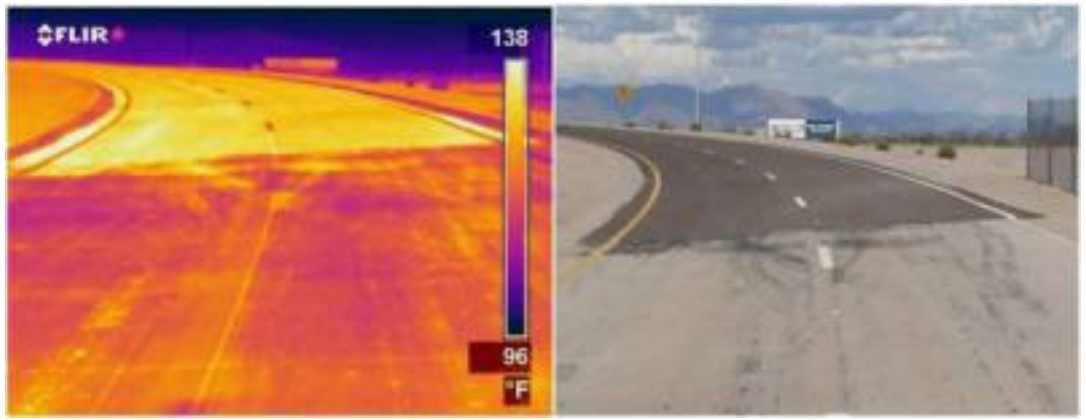
Higher albedo pavements tend to stay cooler in the sun than conventional

- Albedo:
  - Fraction of solar radiation reflected from a surface
- High albedo pavements …
  - Store less heat
  - Have lower surface temperature
  - Reflect more energy (climate benefit in the form of negative radiative forcing)





[Cool Pavements | HeatIsland.LBL.gov]

What will we discuss today …

Radiative forcing (RF) effect on climate change can be estimated at local scale

Impact of pavement albedo on climate change is significant

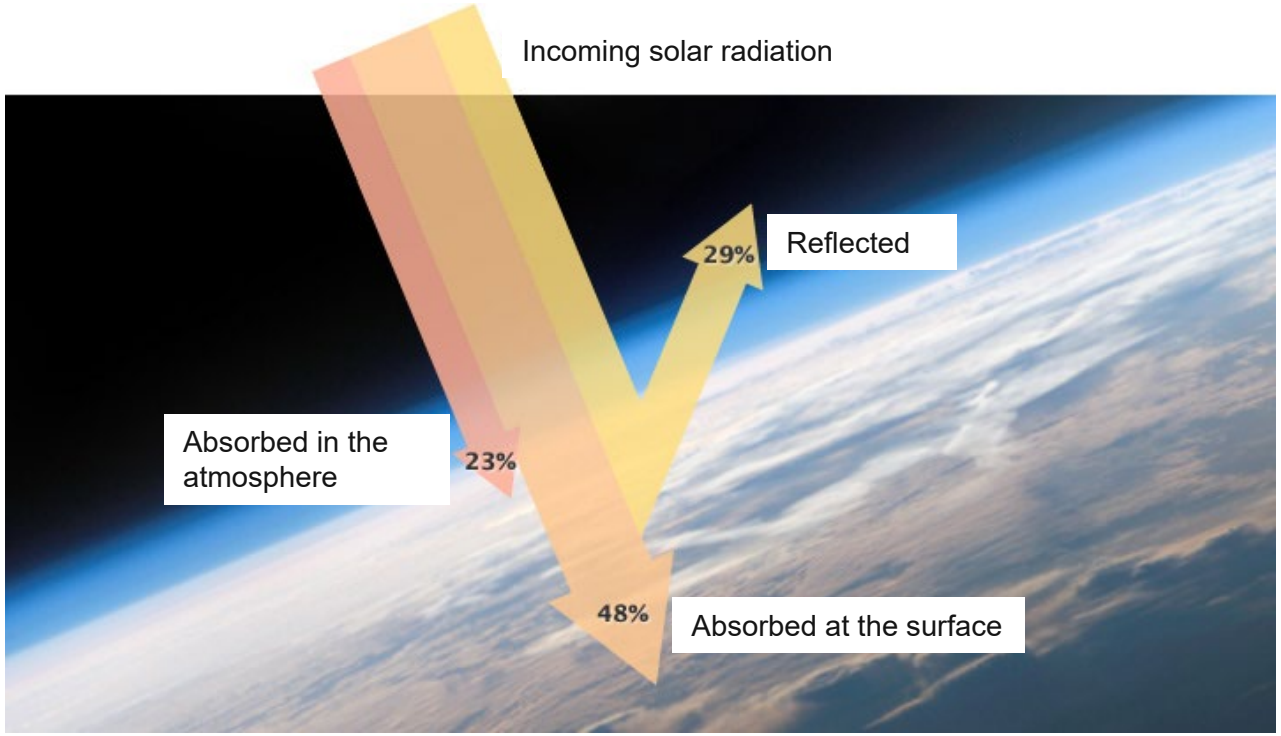
In urban settings, the city configuration should be considered

Building energy demand savings can intensify the climate change benefits

Why do we care about albedo?
Brief introduction to the mechanism of global warming

- Global warming is a result of a change in Earth's energy balance
  - Called a radiative forcing

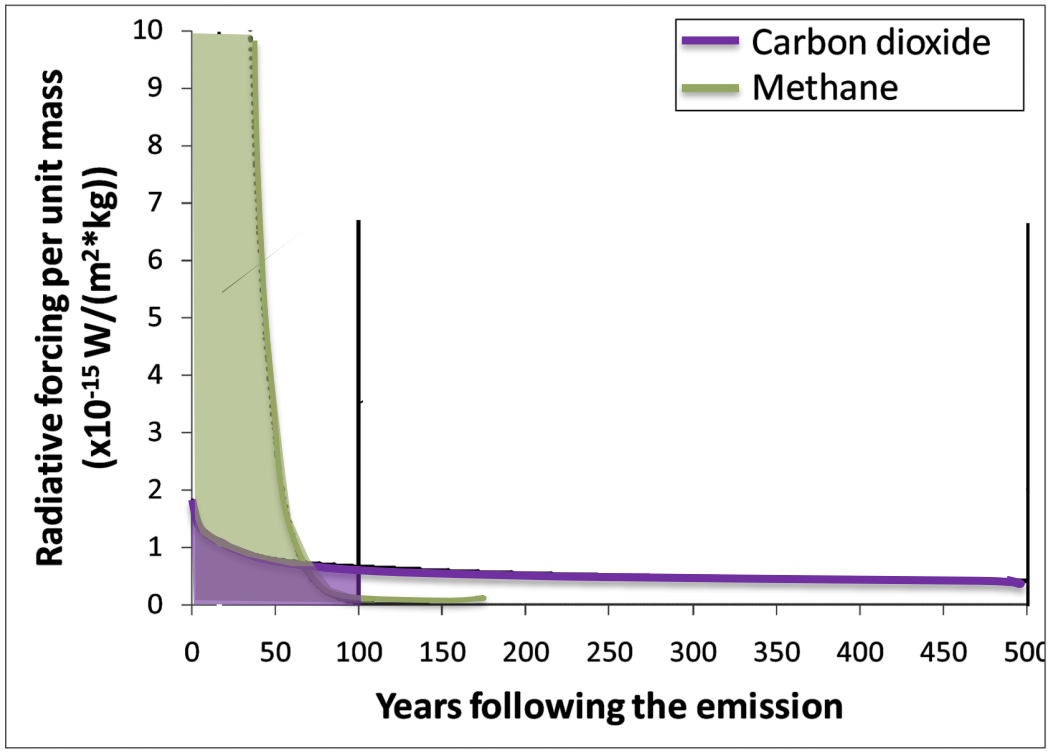
- Several "climate forcers" affect radiative balance:
  - Greenhouse gases (GHGs)
  - Aerosols
  - Surface reflectivity (albedo) change



https://earthobservatory.nasa.gov/features/EnergyBalance/page4.php

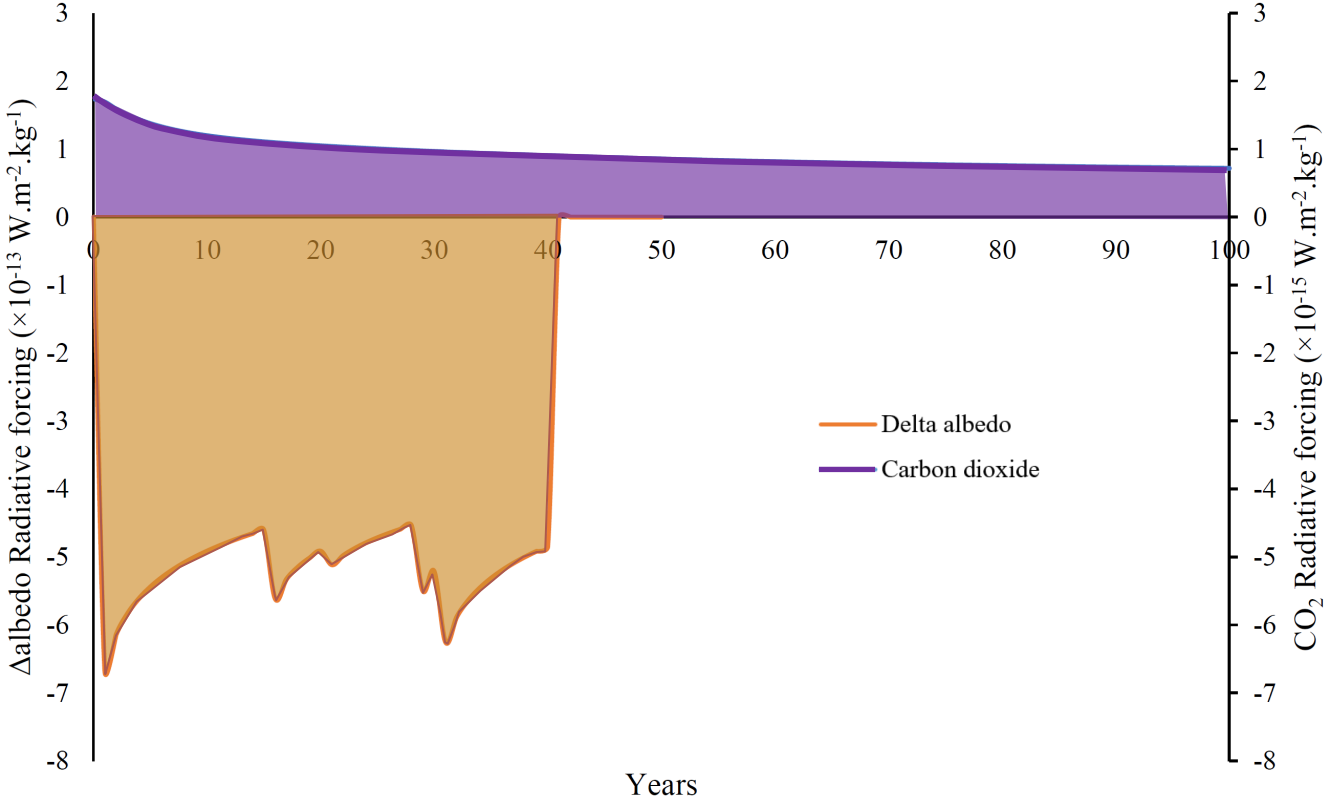
Albedo-induced radiative forcing (RF) impact on climate change can be estimated in the same way done for greenhouse gases

Example of methane emission



$$\mathrm{GWI}_{\mathrm{CH_4}} = \frac{\text{cumulative RF of } \mathrm{CH_4} \text{ (green area)}}{\text{cumulative RF of } \mathrm{CO_2} \text{ (purple area)}}$$

Example of pavement 0.2 albedo increase (40 years)



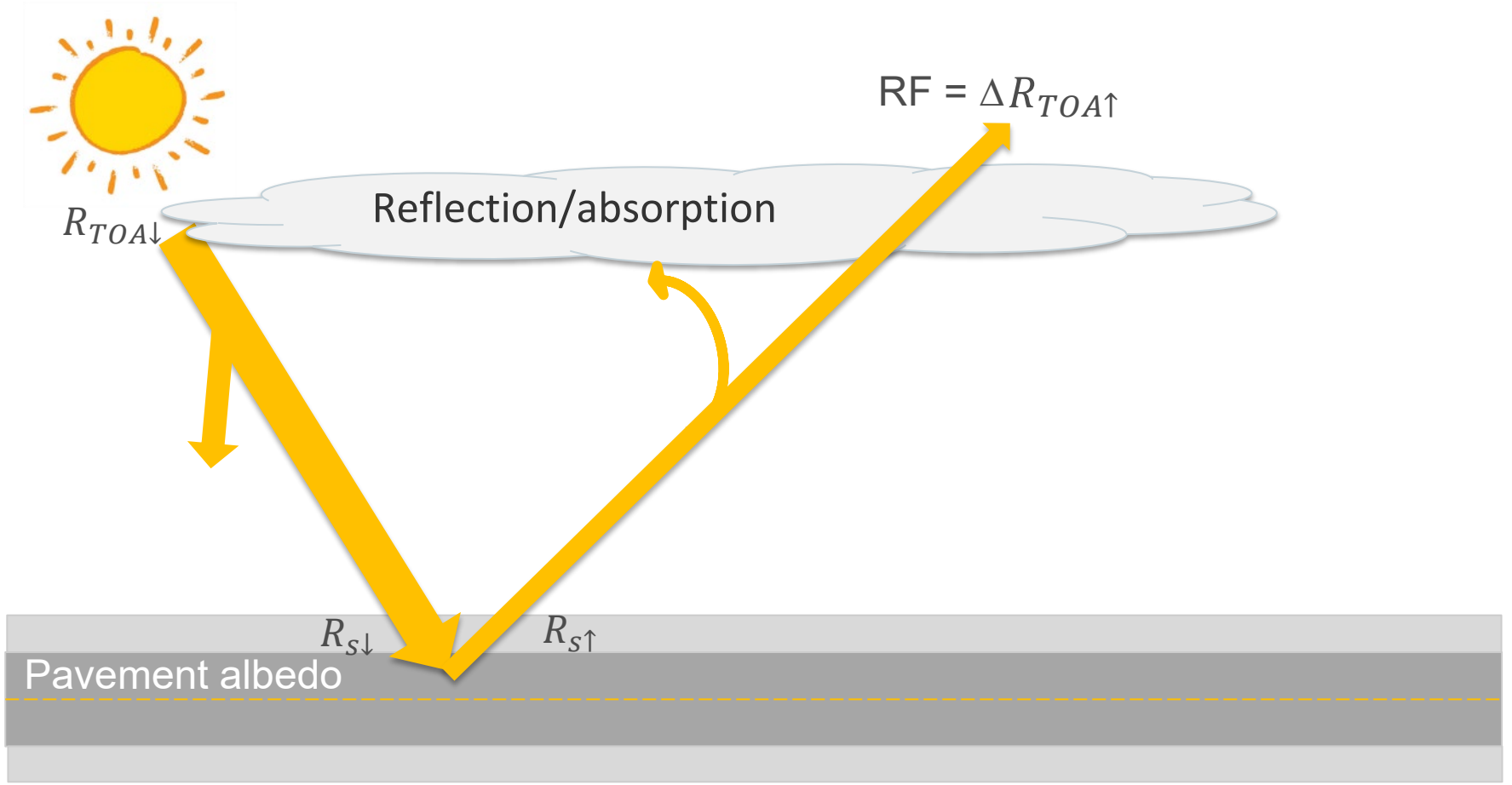
$$\mathrm{GWI}_{\mathrm{albedo}} = \frac{\text{cumulative RF of albedo change (orange area)}}{\text{cumulative RF of } \mathrm{CO_2} \text{ (purple area)}}$$

GWI = Global Warming Impact

The key to estimating location-specific radiative forcing is estimating atmospheric transmittance

Parameters to consider for estimating the atmospheric transmittance:

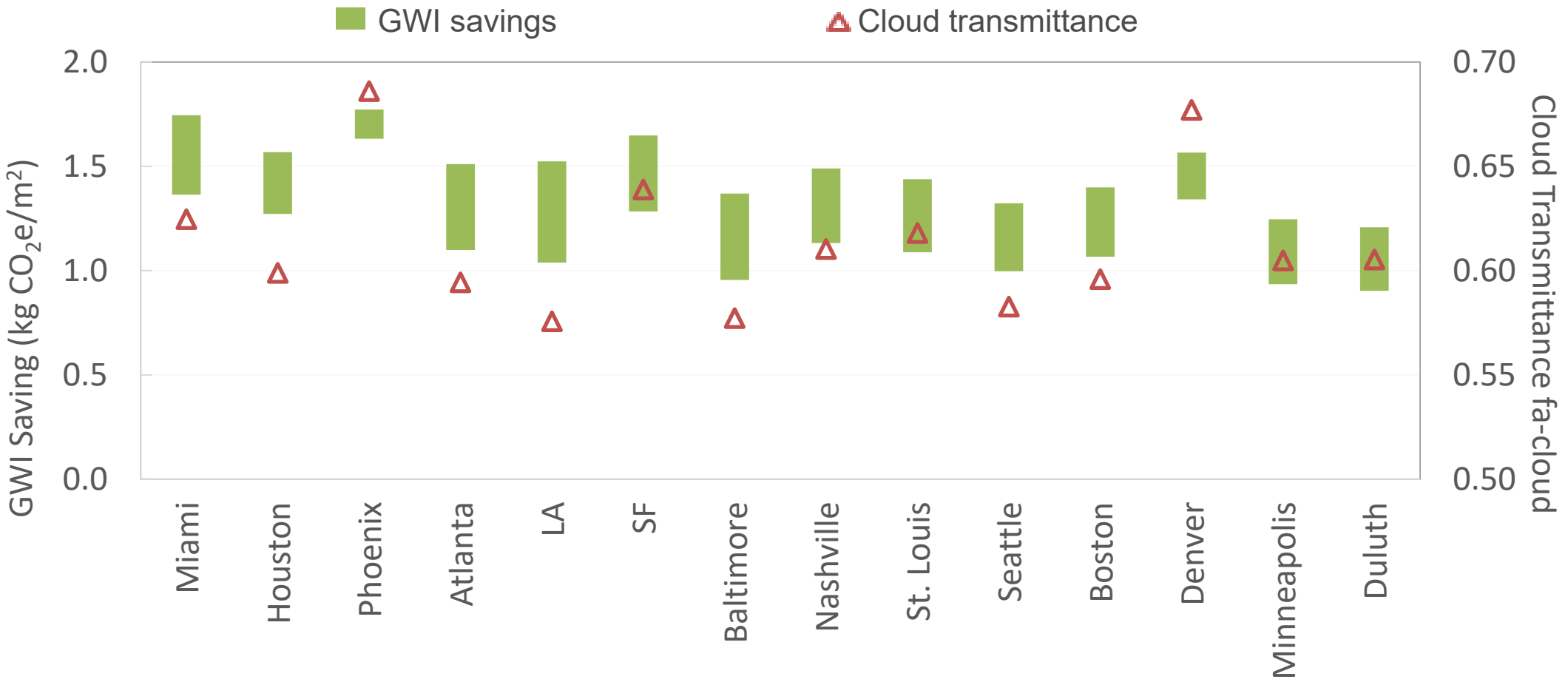
- Location
- Clouds
- Air particles density
- Pavement albedo



R_s = Radiations received / reflected back from a surface
R_{TOA} = Downward/upward Solar radiation at the top of the atmosphere

Location-specific estimate of global warming impact (GWI) mitigation of increasing surface albedo can vary 1-1.6 kg CO_2e/m^2 pavement

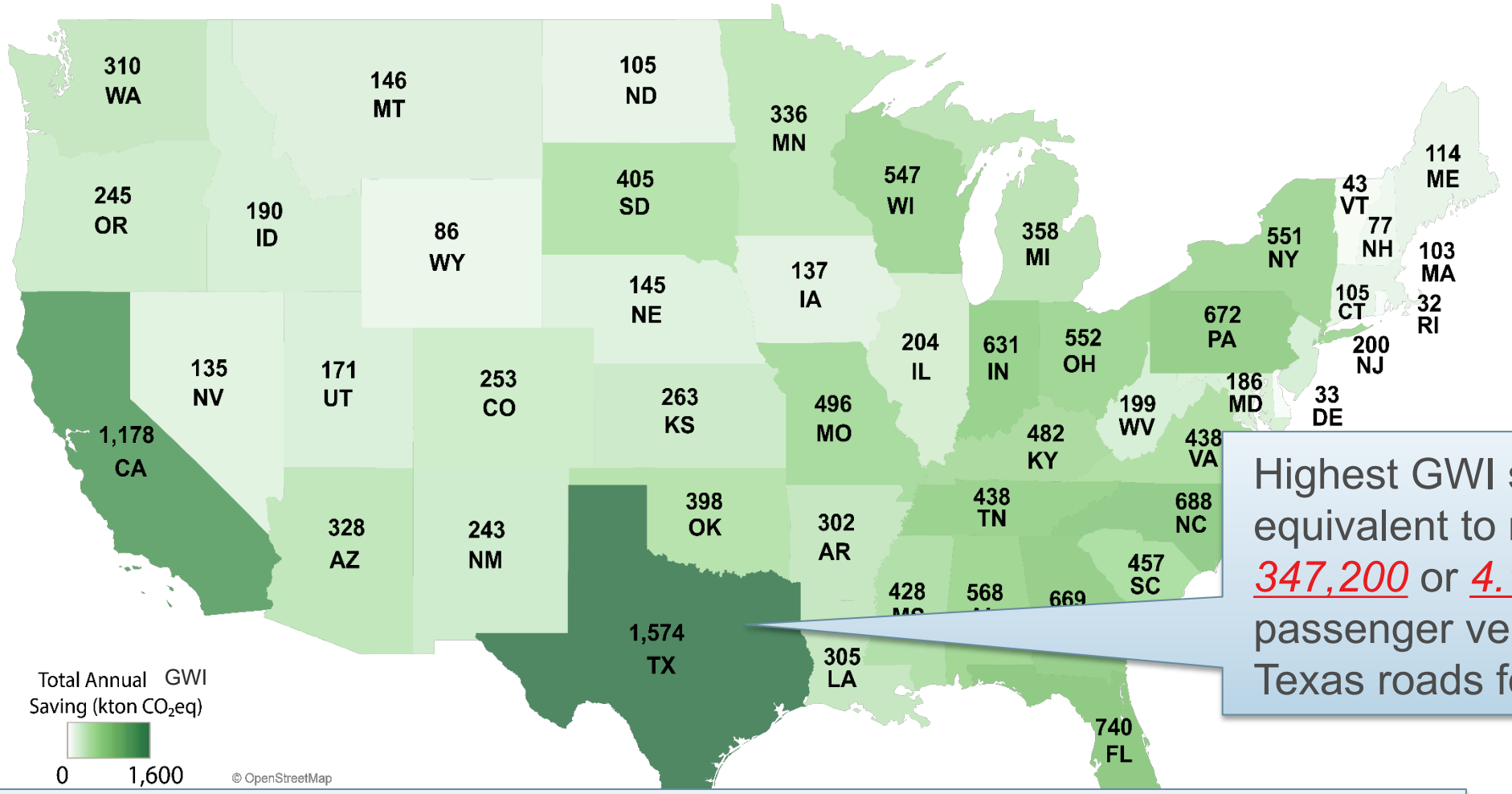
Global warming impact (GWI) savings from RF due to 0.01 increase in surface albedo for the selected 14 locations over 50 years



See the full map: https://cshub.mit.edu/radiative-forcing-dashboard-0

Nationwide analysis of pavement albedo impact on radiative saving (RF) is significant

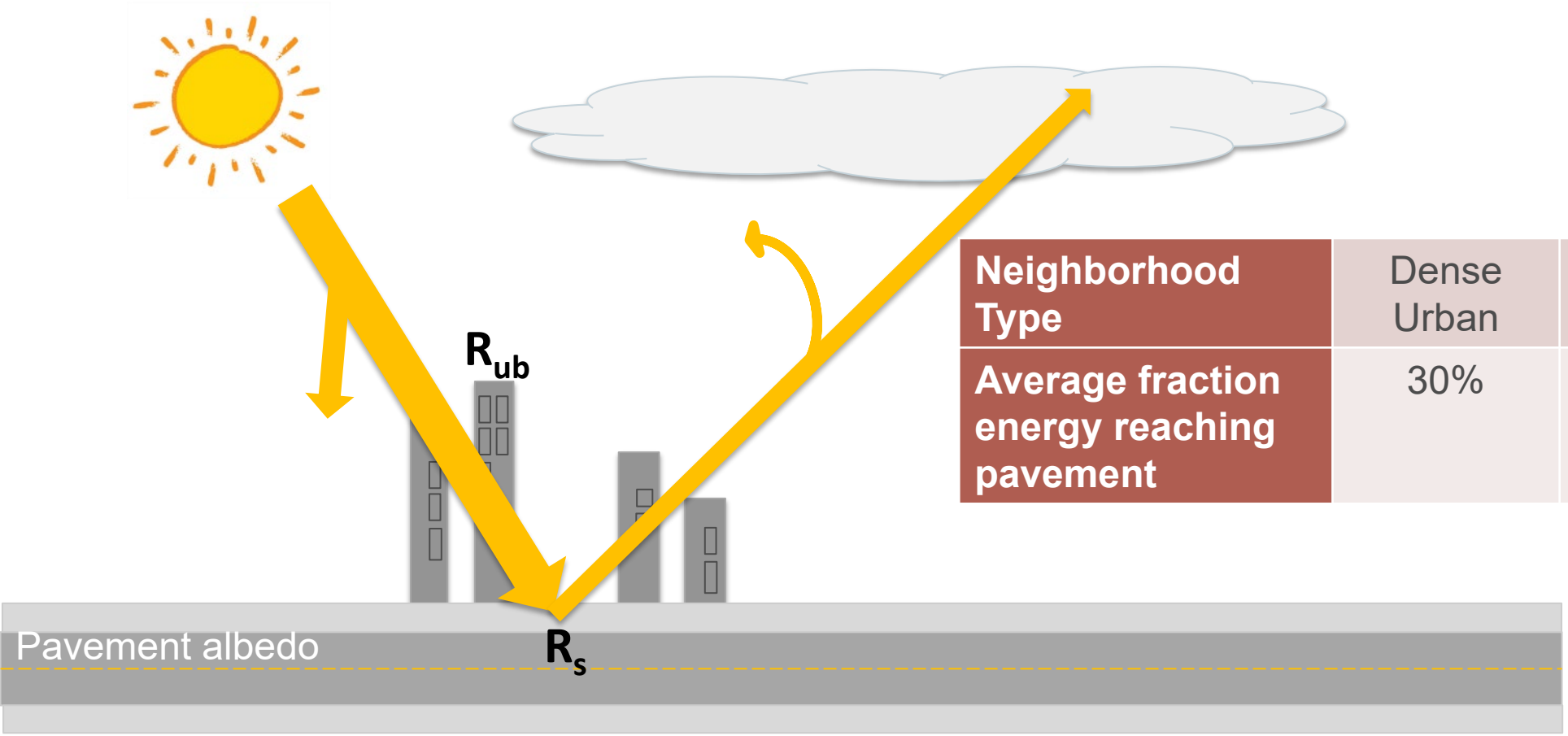
Annual GWI savings from RF due to 0.2 albedo increase in all roads across the U.S.



Highest GWI savings: equivalent to removing *347,200* or *4.1%*, of passenger vehicles from Texas roads for one year.

Nationwide, savings would be equivalent to removing nearly *3.75 million*, or roughly *3.2%,* of passenger vehicles

Context-specific albedo impact on RF should account for shading/trapping effects in urban areas



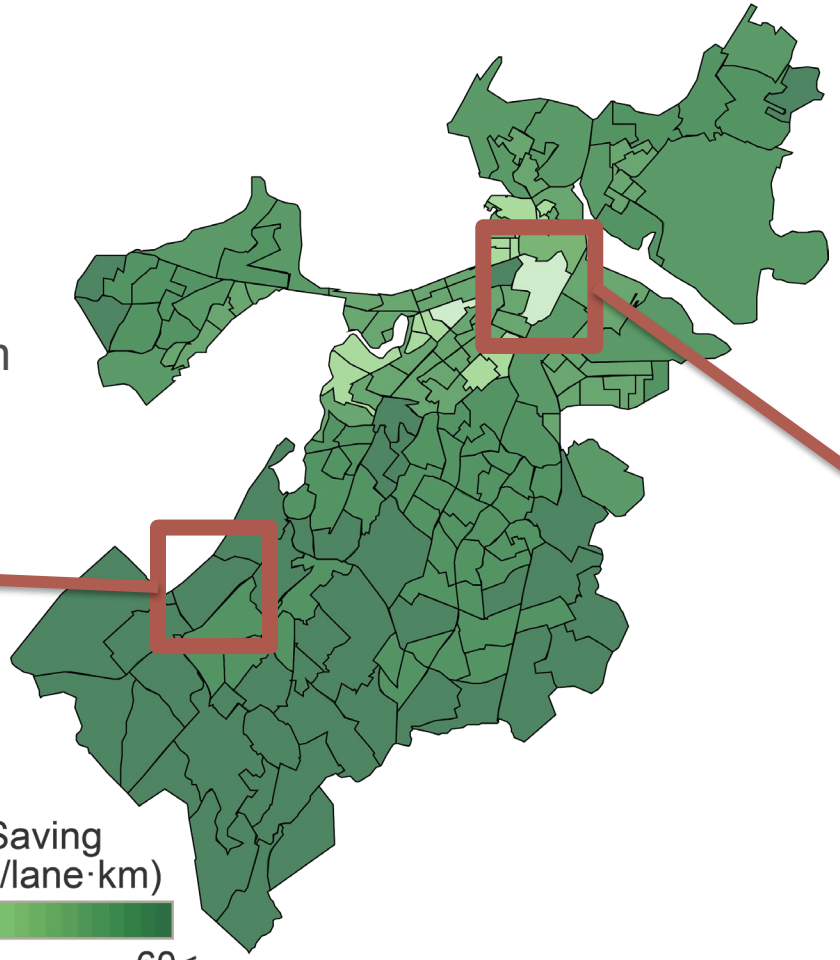
Neighborhood Type	Dense Urban	Moderate Density	Suburbs
Average fraction energy reaching pavement	30%	45 – 75%	90%

R_{ub} = Incoming solar radiation in urban areas
R_s = Reflected solar radiation from the pavement surface

The RF impact on GWI in the city of Boston can vary significantly from one neighborhood to another

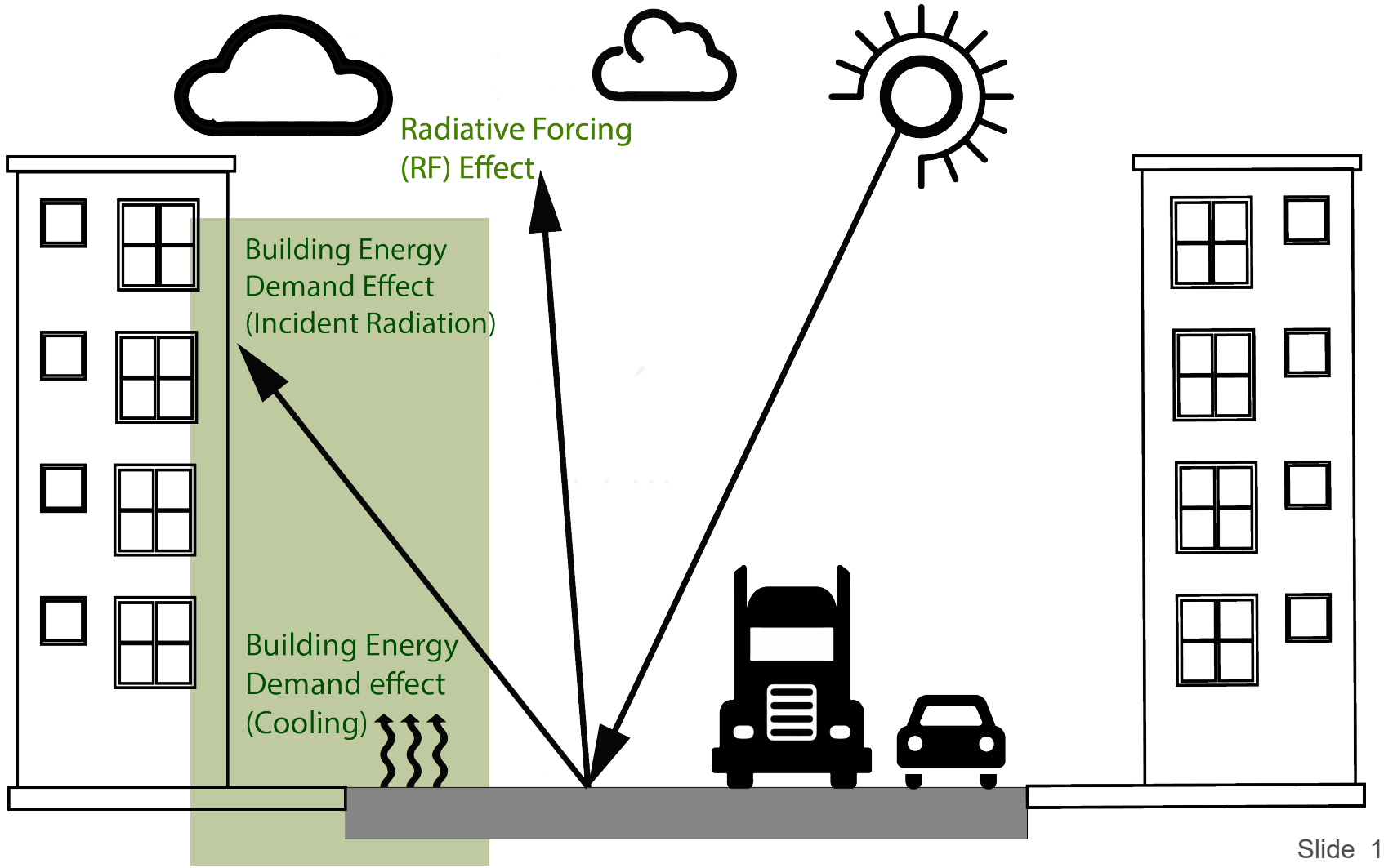
RF impact of increasing the albedo of a lane.km pavement from 0.1 to 0.3 in Boston (analysis period = 50 years)

Roslindale (sparsely built)
RF saving = 69 t CO_2e/lane·km



Downtown
RF saving = 26 t CO_2e/lane·km

Impact of pavement albedo in urban settings includes radiative forcing (RF) effect and building energy demand (BED) change

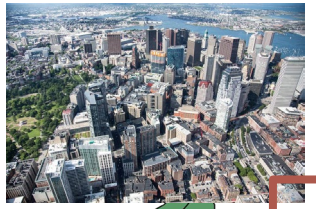


The building energy demand (BED) saving can intensify the climate change mitigation in densely built neighborhoods

RF impact of albedo increase from 0.1 to 0.3

BED impact of albedo increase from 0.1 to 0.3

Net impact of albedo increase from 0.1 to 0.3



RF = Radiative forcing
BED = Building energy demand

Our key messages from today's discussion

Radiative forcing effect on climate change can be estimated at local scale

Impact of pavement albedo on climate change is significant

In urban settings, the city configuration should be considered

Building energy demand savings can intensify the climate change benefits

Thank you for your attention!

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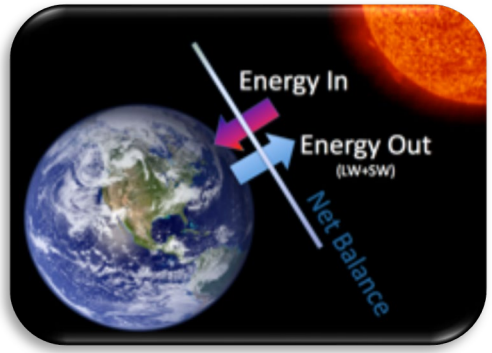
Further information:

- AzariJafari, H., Xu, X., Gregory, J., Kirchain, R. "Urban-Scale Evaluation of Cool Pavement Impacts on the Urban Heat Island Effect and Climate Change." Environmental Science and Technology. August 2021
- Xu, X., Swei, O., Xu, L., Schlosser, C.A., Gregory, J., Kirchain, R. “Quantifying location-specific impacts of pavement albedo on radiative forcing using an analytical approach”, Environmental Science and Technology, 54(4), 2411-2421, 2020
- CSHub Topic Summary, Mitigating Climate Change with Reflective Pavements, August 2021
- Xu, X., AzariJafari, H., Gregory, J., Norford, L., Kirchain, R. "An integrated model for quantifying the impacts of pavement albedo and urban morphology on building energy demand." Energy and Buildings, Volume 211, March 2020
- AzariJafari, Hessam, Ammar Yahia, and Ben Amor. "Removing shadows from consequential LCA through a time-dependent modeling approach: policy-making in the road pavement sector." Environmental science & technology 53.3 (2019): 1087-1097.

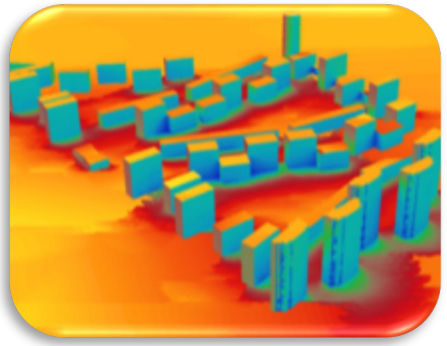
Context-specific albedo impact should account for radiative forcing (RF) and building energy demand (BED) effects in urban areas

Radiative Forcing (RF)



Earth's Energy Balance

Building Energy Demand (BED)



Incident radiation

Cooling

Increasing pavement albedo

- Negative RF
- Cooling benefits

- Increased cooling
- Reduced heating

- Reduced cooling
- Increased heating

NET EFFECT?

The key to estimating location-specific radiative forcing is estimating atmospheric transmittance