SMART SURFACES COALITION

Cooling Cities, Slowing Climate Change and Enhancing Equity:

Costs and Benefits of Smart Surfaces Adoption for Baltimore

This broad, transformative strategy allows cities to become cooler, reduce contribution to climate change, advance equity, protect their economy, and become healthier and more livable.

www.smartsurfacescoalition.org

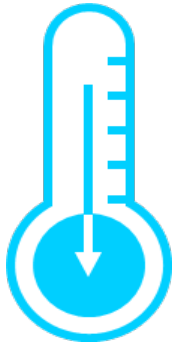
Overview

- Funded by the Abell Foundation and with guidance from local organizations and city leaders, the Smart Surfaces Coalition conducted an in-depth analysis of the costs and benefits of city-wide adoption of Smart Surfaces by Baltimore.
- Analysis includes cost benefit evaluation of 3 lower income Baltimore neighborhoods: Madison East End, Brooklyn Curtis Bay, and Cherry Hill.
- A customized Baltimore-specific online analytic engine was developed to Baltimore to adjust adoption targets and timeframe, to test, compare and optimize Smart Surfaces adoption scenarios, and to select the most effective Smart Surfaces strategy
- By Greg Kats & Rob Jarrell, with supporting author-analysts: Amanda Wager, Jackson Becce, Zach Clayton, Georgia Panitz, Sam Panner, Kalen Davison

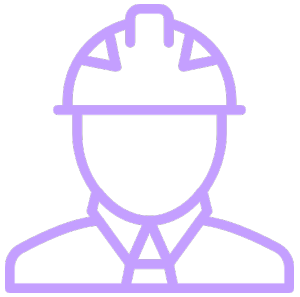
City-wide Baltimore Smart Surface adoption would create:

$13.5 billion *net present value* from adoption of Smart Surfaces*

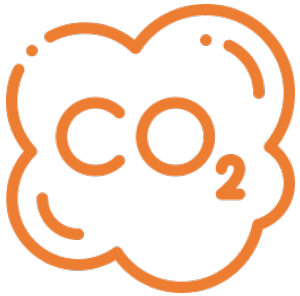
15x more benefits than costs required to implement and maintain this strategy†



4.3°F peak summer temperature reduction *in hottest areas of the city.* With **2.5°F** peak summer temperature reduction on average city-wide¶



3,600 jobs *in first 20-years,* **78,700 job years** created over 30 years §



17 million tonnes carbon reduction impact:
12.4 million tonnes of CO2 avoided + 4.5 million tonnes of CO2 equivalent reduction‡

NOTES:
* In 2020 dollars, at 2% real discount rate over 30 years, 5% avoided summer tourism loss is a very conservative estimate compared to a business-as-usual warming scenario, many surface impacts are not quantified due to lack of rigorous data and/or research
† dollar value of total benefits and total costs over 30 years, in 2020 dollars
‡ in metric tonnes over 30-years. Avoided CO2 from Solar PV generation, and CO2 equivalent from radiative forcing effect of increasing reflectivity. A 3% annual reduction in grid emissions intensity is assumed for business-as-usual baseline/comparison
§ jobs include installation, O&M, and direct materials. One job year equals one full-time job for one year. If avoided job loss from avoiding 5% loss of summer tourism revenue is included total job years created + saved is estimated at over 124,400 job years
¶ ambient air temperature from reflective surfaces and radiative shading effect from trees, not including evapotranspiration cooling and reduced A/C heat ejection so actual temperature reduction is likely higher

Like many cities, Baltimore is becoming hotter, & less livable — particularly in low-income areas.

- Dark urban surfaces absorb, rather than reflect, most of the sun's heat – heating the city and planet
- Dark surfaces make cities ~9˚F (~5˚C) degrees warmer in summer on average, and even hotter in lower-income neighborhoods that have less vegetation and more dark surfaces
- Impervious surfaces increase flooding, mold and water pollution

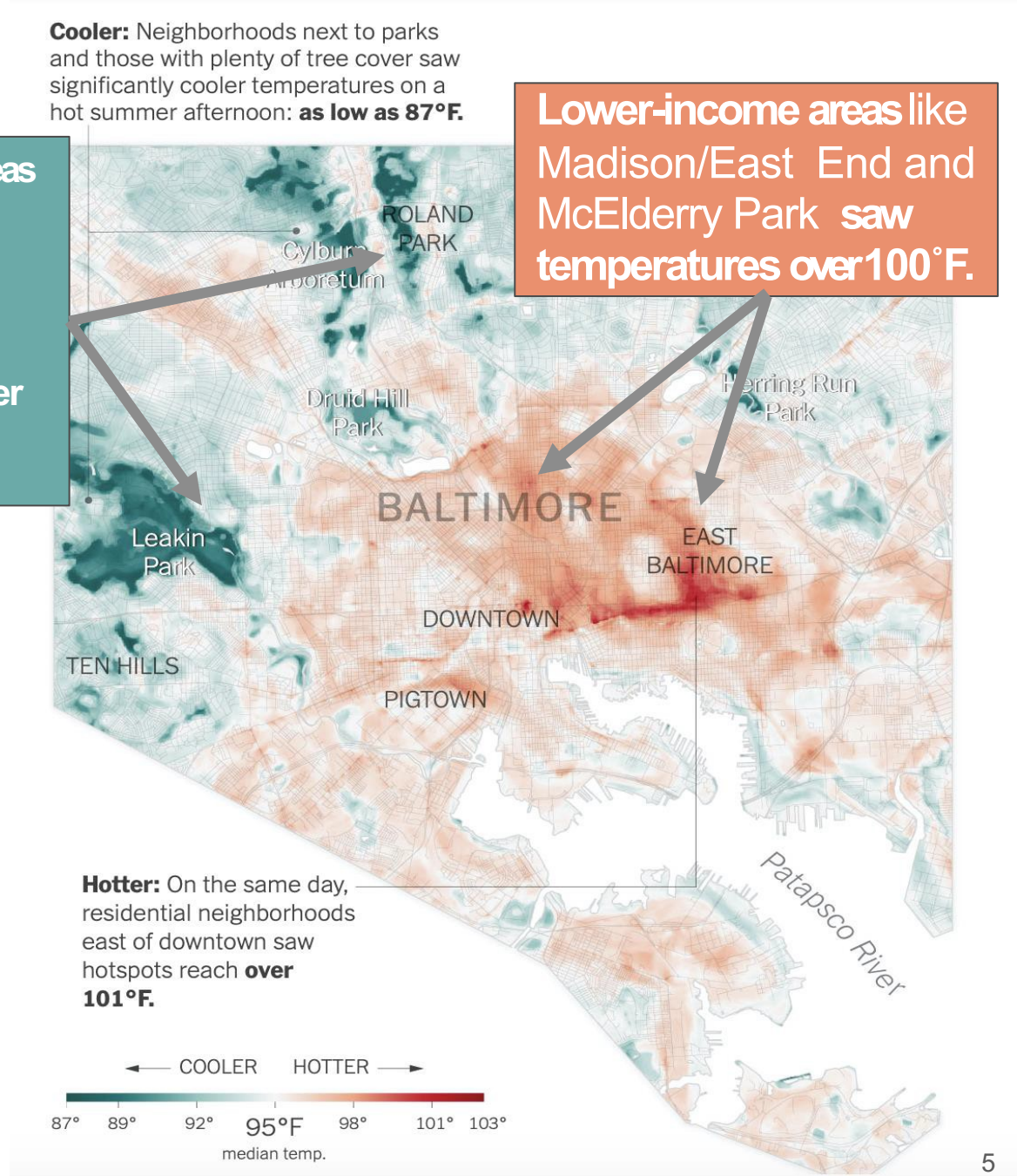


Image courtesy of the New York Times, from data gathered by SSC partner Vivek Shandas/CAPA Strategies

Smart Surfaces allow cities to better manage sun and rain to cut costs and increase livability.

Reflective roofs are light colored and reflect most light and heat, much of which exits the atmosphere, slowing global warming.

Green roofs provide shading, reduce building energy use, clean the air, and absorb and clean water.

Porous pavements allow rain to recharge ground-water - and reduce pollution, storm water runoff, and flood risk.

Click here to watch a brief video on smart surface adoption.

Solar PV converts sunshine into electricity and provides shading for buildings, sidewalks, and other public areas.

Trees reduce temperature by providing shade, clean air of pollutants, reduce flooding risk, and sequester carbon.

Reflective roads and highways cut global warming, reduce pollution and city air temperature, address environmental justice issues cost effectively and are job creative.

Combined Solutions such as solar PV on green roofs help manage both sun and rain, while increasing energy output.

Baltimore Smart Surfaces Adoption: Target Scenario

20-year adoption period, analysis extends 10 years beyond adoption period

Roofing Targets				
Surface Kind	**Cool Roofs**	**Bioswale-managed ***	**Green Roofs**	**Solar PV****
Low slope roofs	80%	20%	2%	40%
Steep slope roofs	20%	N/A	N/A	20%
Adoption Timeframe	20 years	20 years	20 years	20 years

Pavement Targets			
Surface Type	**Reflective**	**Porous *** **	**Bioswale-managed***
Parking	50%	5%	20%
Streets	15%	N/A	0%
Sidewalk	0%	5%	0%
Adoption Timeframe	20 years	20 years	20 years

Urban Tree Canopy Targets	
Surface Kind	**Tree Canopy**
City Area (% of total)	40%
Adoption Timeframe	20 years

Note: Target % = percent of existing surfaces available (e.g. % of low slope roofs, or % of roads)

*Bioswales/bioretention can manage stormwater runoff from adjacent roofs or parking lots. Bioswale-managed roofs and parking lots are calculated using SF or % of the area managed by a bioswale, not SF of bioswale -- the size of the bioswale is about 4.5% of the impervious area managed. (eg a small area of bioswale or tree trench can manage the water runoff of a much larger hard surface).

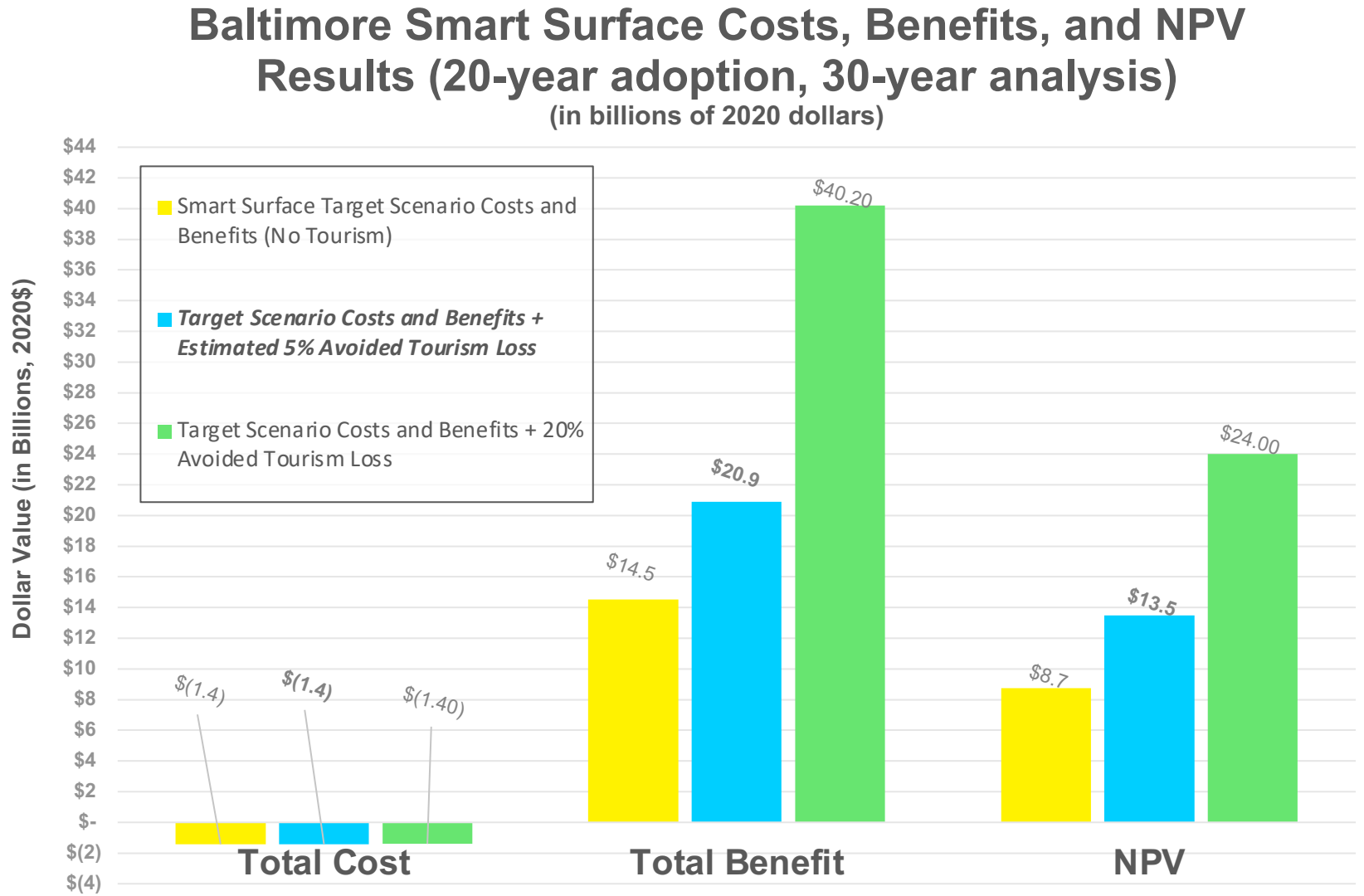
** PV Can be put on any roof (e.g. PV can go on a regular roof, green roofs, or reflective/cool roofs, and standard roofs).

*** Permeable parking only applied when a parking lot is ripped out and replaced, at which time it costs less to make the area permeable (grid-grass or grid-gravel) than to construct a new asphalt parking surface. Total Cost in this case is therefore positive number because it costs less to install permeable parking when the hard surface parking lot is replaced, reflecting a first cost savings.

Smart Surfaces benefits for Baltimore would be 15x larger than costs

Target Scenario Results

- Total cost: $1.4 billion
- Total benefits: $20.9 billion
- NPV: $13.5 billion
- Benefit-Cost Ratio: 15:1
- Includes avoided loss of 5% of summer tourism



Managing Sun: Reflective Surfaces Overview

OBJECTIVE:

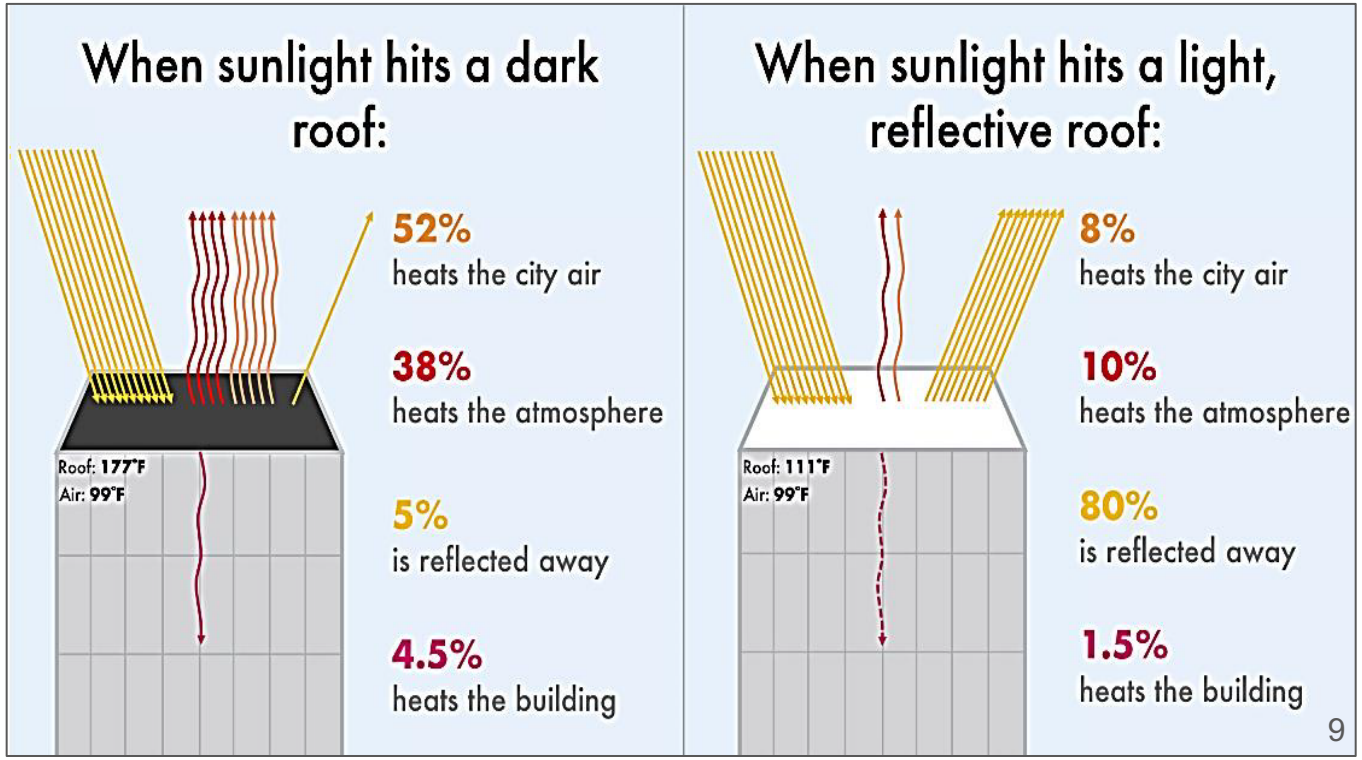
- Increase reflectivity of roofs, roads, and parking lots to reflect most incoming light and heat back into space – cooling cities and slowing global warming.
- Reflective surfaces also cool the building below (if roof) or nearby (if pavement) resulting in less A/C and lower energy bills, further reducing temperature by reducing A/C heat ejection into city air.

MAIN BENEFITS:

- Reduced ambient city air temperature
- Reduced building electricity use
- Extension of surface life
- Reduced Ozone and PM2.5
- Reduced global warming

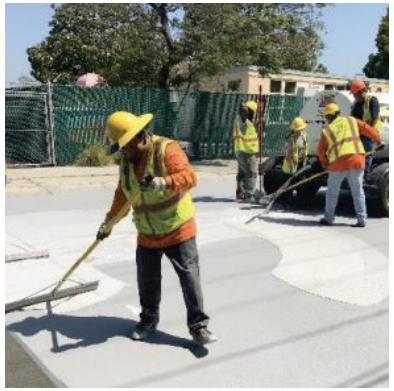
ADOPTION INFO:

- Easy installation, proven technologies
- Very Cost-effective (incremental costs fully recouped from surface life extension: reflective surfaces expand and contract less and last longer)



Managing Sun: Reflective Surfaces Impacts in Baltimore

Cool / Reflective Roof



Reflective Road

Reflective Parking

Reflective Surface:	Adoption Target (over 20 years)	Cost (millions) (2020$)	Benefit (millions) (2020$)	NPV (millions) (2020$)***	Benefit Cost Ratio	Job Years Created	Temperature Reduction Contribution*	CO2-equivalent reduction (metric tons) **
Roofs	80% low-slope, 20% steep-slope	$112	$862	$540.9	8:1	1,900	2.4 °F	3,575,000
Roads	15% of road area	$10	$27	$14.6	3:1	160	0.2 °F	748,000
Parking	50% of lot area	$44	$103	$43.2	2:1	750	0.5 °F	216,000

note: numbers may not sum due to rounding

* Contribution to peak summer (1-4pm) temperature reduction in some of the hottest areas of city (e.g. parts of downtown/central areas of city)
**Reduction in CO2 equivalent over 30-years from reflective surface's effect on radiative forcing
*** Using 2% real discount rate
Tourism-related benefits not included in above surface analysis

Managing Sun: Solar PV Impacts in Baltimore

MAIN BENEFITS:

- Reduces CO2 emissions from electricity generation
- Generates electricity for use by building owner or sold into the grid
- Shades roof, decreasing summer cooling requirement
- Zero-dollar upfront financing options are readily available

ADOPTION INFO:

- Can be installed on flat and steep-slope regular roofs as well as on top of cool and green roofs
- Costs continue to decline as efficiency is increasing (e.g. more electricity from same array area)

Solar PV Surface (roof type)	Adoption Target (over 20 years)	Cost (millions) (2020$)*	Benefit (millions) (2020$)	NPV (millions) (2020$)**	Benefit Cost Ratio	Job Years Created***	Avoided CO2 emissions (metric tons)
Low-slope	40%	$320	$7,322	$4,638	23:1	40,500	8,907,000
Steep-slope	20%	$155	$3,282	$2,067	21:1	20,600	3,492,000
TOTAL		**$474**	**$10,604**	**$6,704**	**22:1**	**61,000**	**12,399,000**

note: numbers may not sum due to rounding

* Assumes Solar PV is third-party financed, with electricity savings accruing to financier during first 10 years
** Using 2% real discount rate
*** Job years over 30-years, 1 job year = 1 full-time job for one year
Tourism-related benefits not included in above surface analysis

Managing Rain: Porous Pavement and Bioswale/Raingarden Overview & Impacts on Baltimore

ABOUT: Bioswales, raingardens, and other forms of bioretention reduce stormwater runoff, risk of flooding and stormwater system overflow by allowing rain to run off into green, porous basins, recharging groundwater.

Surface:	Adoption Target (over 20 years)	Cost (millions) (2020$)	Benefit (millions) (2020$)	NPV (millions) (2020$)**	Benefit Cost Ratio	Job Years Created
Porous/Permeable:						
Parking	5% of lot area	+$48*	$113	$110	14:1	*
Sidewalk	5% of sidewalks	$49	$200	$99	4:1	539
*Bioswale/Raingarden-managed:***						
Parking	20% of lot area	$100	$578	$321	6:1	1,700
Roofs	20% low-slope	$99	$549	$301	6:1	1,400

note: numbers may not sum due to rounding

* Permeable parking only applied when a parking lot is ripped out and replaced, at which time it costs less (and is less labor-intensive) to make the area permeable (grid-grass or grid-gravel) than to construct a new asphalt parking surface. Total Cost in this case is therefore positive number, reflecting a first cost savings.

** using a 2% real discount rate

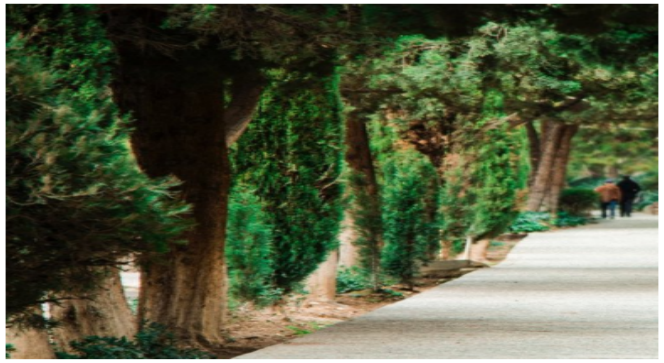
*** Bioswales/bioretention can manage stormwater runoff from larger, adjacent roofs or parking lots. Bioswale-managed roofs and parking lots are calculated using SF or % of the area managed by a bioswale. A small area of bioswale or tree trench can manage the water runoff of a much larger hard surface.

Tourism-related benefits not included in above surface analysis

Managing Sun & Rain: Urban Trees Overview

Baltimore has an aggressive goal of 40% tree cover by 2040 and is one of the few cities actually increasing tree coverage. Increasing tree canopy has many benefits, including:

- Reduces temperature and increase shade
- Reduces flooding
- Reduces air-pollution and cuts noise
- Improve aesthetics and livability
- Sequesters carbon



Managing Sun & Rain: Green Roofs Overview

Green roofs are roofs covered in vegetation, which provides many benefits:

- Reduces energy use
- Reduces air-pollution
- Reduces flooding and absorbs and manages rain
- Extends roof life
- Increases biodiversity
- Increases city resilience and livability

Managing Sun & Rain: Urban Trees & Green Roofs
Impacts for Baltimore

	Adoption Target (over 20 years)	Cost (millions) (2020$)	Benefit (millions) (2020$)	NPV (millions) (2020$)**	Benefit Cost Ratio	Job Years Created	Temperature Reduction Contribution
Urban Tree Canopy	40% of city area*	$500	$1,330	$560	3:1	10,000	1.21°F ***
Green Roofs	2% of low-slope	$81	$158	$46	2:1	1,300	not quantified

note: numbers may not sum due to rounding

* Full 40% canopy coverage will occur approximately 10 years after year 20 of adoption assuming O&M continues
** Using 2% real discount rate
*** Temperature reduction is due to radiative shading effect of trees and does not include effect of evapotranspiration
Tourism-related benefits not included in above surface analysis

Baltimore Results Overview: 20-year Adoption Scenario

30-year analysis period (ongoing costs and benefits extend 10 years beyond adoption period)

BALTIMORE: (20-YEAR ADOPTION SCENARIO, 30-YEAR ANALYSIS) CONSOLIDATED SUMMARY							
Smart Surface	Target	Costs (2020$)	Benefits (2020$)	NPV (2020$, 2% Real Discount Rate)	Benefit:Cost Ratio (from 2020$)	Employment (job yrs)	Peak Period Summer Temp Reduction Estimate ****
Reflective (Cool) Roofs **	Low-slope roof area: 80% Steep-slope roof area: 20%	$ (112,021,921)	$ 861,699,715	$ 540,883,629	7.69	1,904	2.41 °F
Bioswale-managed Roof *****	Low-slope roof area: 20%	$ (99,391,531)	$ 549,322,190	$ 301,406,117	5.53	1,391	not included
Green Roofs	Low-slope roof area: 2%	$ (81,248,064)	$ 158,121,898	$ 45,631,460	1.95	1,300	not included
Solar PV*	Low-slope roof area: 40% Steep-slope roof area: 20%	$ (474,275,239)	$ 10,603,617,426	$ 6,704,265,572	22.36	61,042	not included
Reflective Parking**	Parking area: 50%	$ (43,881,312)	$ 102,805,859	$ 43,212,786	2.34	746	0.52 °F
Permeable Parking ***	Parking area: 5%	$ 48,451,570	$ 112,644,481	$ 110,397,261	14.40		not included
Bioswale-managed parking*****	Parking area: 20%	$ (99,898,491)	$ 577,725,286	$ 320,637,416	5.78	1,698	not included
Reflective Roads**	Road area: 15%	$ (9,519,821)	$ 27,197,185	$ 14,552,521	2.86	162	0.16 °F
Permeable Sidewalks	Sidewalk area: 5%	$ (49,027,682)	$ 200,361,328	$ 98,511,475	4.09	539	not included
Trees ****	City land area: 40%	$ (499,089,278)	$ 1,330,110,900	$ 559,553,468	2.67	9,982	1.21 °F
TOTAL		**$ (1,419,901,769)**	**$ 14,523,606,267**	**$ 8,739,051,705**	**10 : 1**	**78,765**	**4.3 °F**
5% Avoided Tourism Loss******	5% of summer tourism		$ 6,420,000,000	$ 4,792,841,488		51,848	
Total with 5%Tourism Benefit		**$ (1,419,901,769)**	**$ 20,943,606,267**	**$ 13,531,893,193**	**15 : 1**	**130,613**	**4.3 °F**
10% Avoided Tourism Loss			$ 12,840,000,000	$ 9,585,682,976		103,697	
Total with 10% Tourism Benefit		**$ (1,419,901,769)**	**$ 27,363,606,267**	**$ 18,324,734,681**	**19 : 1**	**182,461**	**4.3 °F**
20% Avoided Tourism Loss			$ 25,680,000,000	$ 19,171,365,952		207,394	
Total with 20% Tourism Benefit		**$ (1,419,901,769)**	**$ 40,203,606,267**	**$ 23,964,207,440**	**28 : 1**	**286,158**	**4.3 °F**

* See applicable notes on previous slides

Importance of Scaling Smart Surfaces in Baltimore

Mark Conway

Baltimore City Councilmember, and Executive Vice-President at the Chesapeake Conservancy

"Baltimore—particularly our lower-income communities—already suffer from harsher summer heat, weather that will grow all the worse with climate change. And our response to heightened temperatures and urban heat islands must be as smart as it is comprehensive. This landmark report makes clear that broad adoption of Smart Surfaces strategies would cool our city, cut pollution, create jobs, strengthen our economy, and redress longstanding environmental injustice. Baltimore has powerful allies in the Smart Surfaces Coalition and its partners in our quest for a stronger and healthier city."

Georges C. Benjamin, MD

Executive Director, American Public Health Association & former Sec. of Health for Maryland

"Extreme heat in urban communities like Baltimore imposes enormous health and financial costs, including increased heat-related deaths. This is especially true in underserved and low-income minority neighborhoods. Adoption of Smart Surfaces city-wide is an essential strategy to address the devastating impacts of climate change and achieve a cooler and healthier city. This report demonstrates how and why Baltimore's leaders, with state support, should move quickly to adopt Smart Surfaces."

Chris Riehl

President of the Baltimore Tourism Association:

"Incorporating Smart Surfaces in Baltimore will overall improve the livability and appeal of the city, allowing the city to market itself as more sustainable, energy efficient, and desirable tourism destination."

Changing How City Surface Decisions Are Made:

Today

Governments and foundations spend billions of dollars to pilot and promote single solutions such as urban trees or porous or reflective surfaces.

But…cities are *still* getting hotter and more polluted, and are losing tree canopy…why?

City infrastructure decisions are made by **city departments** that **lack the expertise, authority or tools to quantify and understand critical costs and benefits** including city heat, air and water quality, human health, equity, employment, livability, city bond rating and climate

With Smart Surfaces Coalition

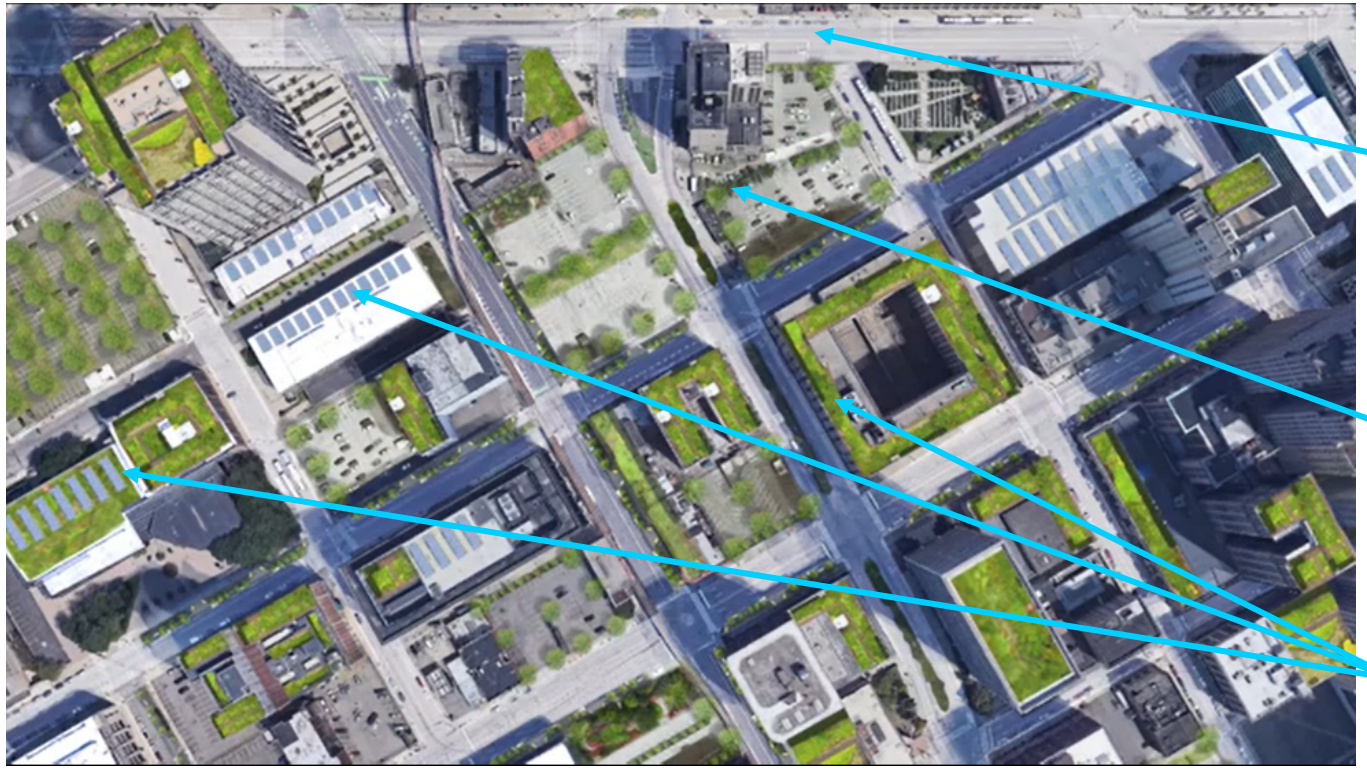
For cities to adopt reflective, porous and green surfaces and trees at scale requires that costs and benefits be fully quantified and included in design decisions.

How does the Smart Surfaces Coalition do this?

- Organize surface solutions in a single framework to enable city-wide analysis and adoption
- Build tools for cities to quantify the full costs and benefits of all surface options, model design scenarios, and make fully informed surface design decisions
- Directly support cities through integrated training, guidance, and analysis through a Coalition of leading organizations that cities already trust

Future Smart Surface City Norm:

Covered in light-colored/reflective, porous, and green surfaces, trees, and rooftop solar PV → a cost-effective solution for more livable cities.



Light-colored, reflective roads:
- Reduced heat absorption, reduces ambient temperature
- Porous parking lanes manage stormwater and reduce runoff

Porous, reflective parking lots with trees:
- Increased thermal comfort
- Shading and stormwater management

Reflective, green and PV roofs:
- Reduced building and city temperature
- Reduced runoff
- Generating clean renewable energy

Guiding the Coalition:

Steering Committee (strategy decisions)

- **Greg Kats (co-chair)** – Author of Greening Our Built World: Costs Benefits and Strategies
- **Vivian Loftness (co-chair)** – Former Head of School of Architecture at Carnegie Mellon
- **Georges Benjamin, MD** – Executive Director of the American Public Health Association
- **Rashad Kaldany** – former COO of the International Finance Corporation
- **Julie T. Katzman** – former COO of the Inter-American Development Bank
- **William H. Lamar IV** – Pastor of Metropolitan African Methodist Episcopal Church
- **Ian Riley** – CEO, World Cement Association and Partner, WhitewaterTx
- **Jennifer Roberts** – Former Mayor of Charlotte, Director of Path to Positive Communities at ecoAmerica
- **Durwood Zaelke** – President of the Institute for Governance and Sustainable Development
- **Anica Landreneau**– Director of Sustainable Design at HOK
- **Chris Leinberger** – President of Locus, also at GWU and at Brookings
- **Cooper Martin** – Director, Sustainable Cities Institute, National League of Cities
- **Cynthia Koehler** – Executive Director, WaterNow Alliance
- **Mark Conway –** Executive VP at Chesapeake Conservancy and Baltimore City Councilmember
- **Brendan Shane** -- Climate Director, Trust for Public Lands, former C-40 Regional Director for North America
- **Dr. Radhika Khosla** – Research Director of the Oxford India Centre for Sustainable Development
- **Will Wynn** – former two-term Mayor of Austin, TX
- **Kurt Shickman** – CEO, Global Cool City Alliance

Board of Directors (fiduciary oversight)

- **Frank Loy (chair)** – former Under Secretary of State for Global Affairs, former board chair of Environmental Defense Fund, Resources for the Future, and League of Conservation Voters
- **Carolina Barco** – former Foreign Minister for Colombia, Ambassador to the U.S.
- **Tracy Wolstencroft** – former President of National Geographic Society, former partner at Goldman Sachs
- **Greg Kats** – former Managing Director, Good Energies, Inc.