

# Washington, DC Smart Roof Cost-Benefit Report Summary – 04/2015



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# DC Smart Roof Mapping Initiative

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- **Chris Pyke** – VP Research, U.S. Green Building Council (now Chief Operating Officer at GRESB)

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- **Keith Anderson, Evan Branosky, Emily Rice, Jeff Seltzer, Young Tsuei, Bill Updike, Brian Van Wye, and Jay Wilson** – District Department of the Environment
- **Mark Chambers** – Department of General Services
- **Bob Hoehn and Dave Nowak** – U.S. Forest Service
- **David Sailor** – Portland State University
- **Sam Brooks** – ClearRock
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- **Paul Lanning** – Bluefin LLC
- **Kurt Shickman** – Global Cool Cities Alliance

# Opportunity/Need

- Washington, DC has aggressive energy, greening, and health objectives, embodied in Sustainable DC
- The District's Department of General Services (DGS) is greening its portfolio of 28 million ft<sup>2</sup>, including 11 million ft<sup>2</sup> of roofs (of which 9 million ft<sup>2</sup> are low slope)
  - This study focuses on these DGS facilities
- Washington, DC and other cities increasingly deploy reflective (cool) and vegetated (green) roofs and solar PV on their roofs
  - On city-owned office buildings and schools
  - On non-city-owned buildings through requirements and incentives
- No city or organization has quantified the full set of costs and benefits for these various roof options
- There is currently no rigorous basis for designing comprehensive roof upgrade programs in Washington, DC or any other city or city subregion

# Benefits estimated for cool roofs

- Direct and indirect (urban heat island-related) energy savings
  - Reduced building energy use → lower energy costs
- Reduced ozone and fine particle (PM<sub>2.5</sub>) pollution
  - Reduced incidences of respiratory (e.g., worsened asthma, inflammation) and cardiovascular (e.g., heart disease) health problems and reduced mortality → lower healthcare expenditures
- Reduced heat-related mortality
  - Fewer deaths during the warm season that are related to the urban heat island → lower healthcare expenditures
- Reduced greenhouse gas (GHG) emissions
  - Reduced climate change impacts → decreased economic damage due to climate change

# Benefits estimated for green roofs

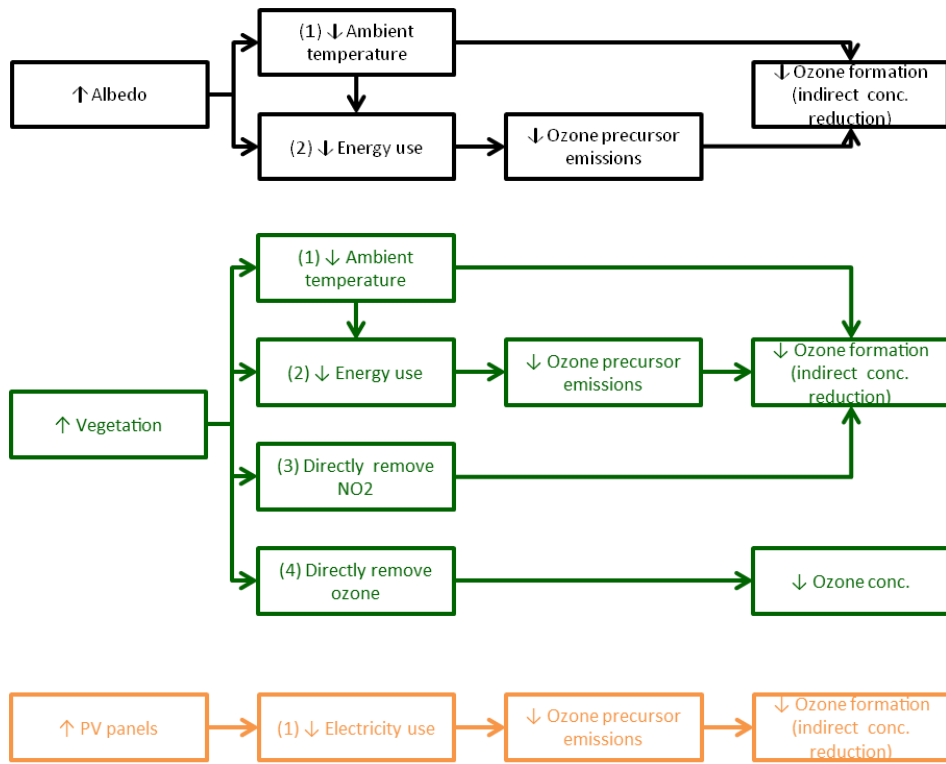
- Direct and indirect (urban heat island-related) energy savings
  - Reduced building energy use → lower energy costs
- Reduced ozone and fine particle (PM<sub>2.5</sub>) pollution
  - Reduced incidences of respiratory (e.g., worsened asthma, inflammation) and cardiovascular (e.g., heart disease) health problems and reduce mortality → lower healthcare expenditures
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- Reduced GHG emissions
  - Reduced climate change impacts → decreased economic damage due to climate change
- Reduced stormwater runoff
  - Reduced stormwater runoff from the roof that contributes to combined sewer overflows and flash flooding and that harms local waterbodies and wildlife → revenue from Stormwater Retention Credit program and lower stormwater management costs/fees

# Benefits estimated for solar PV

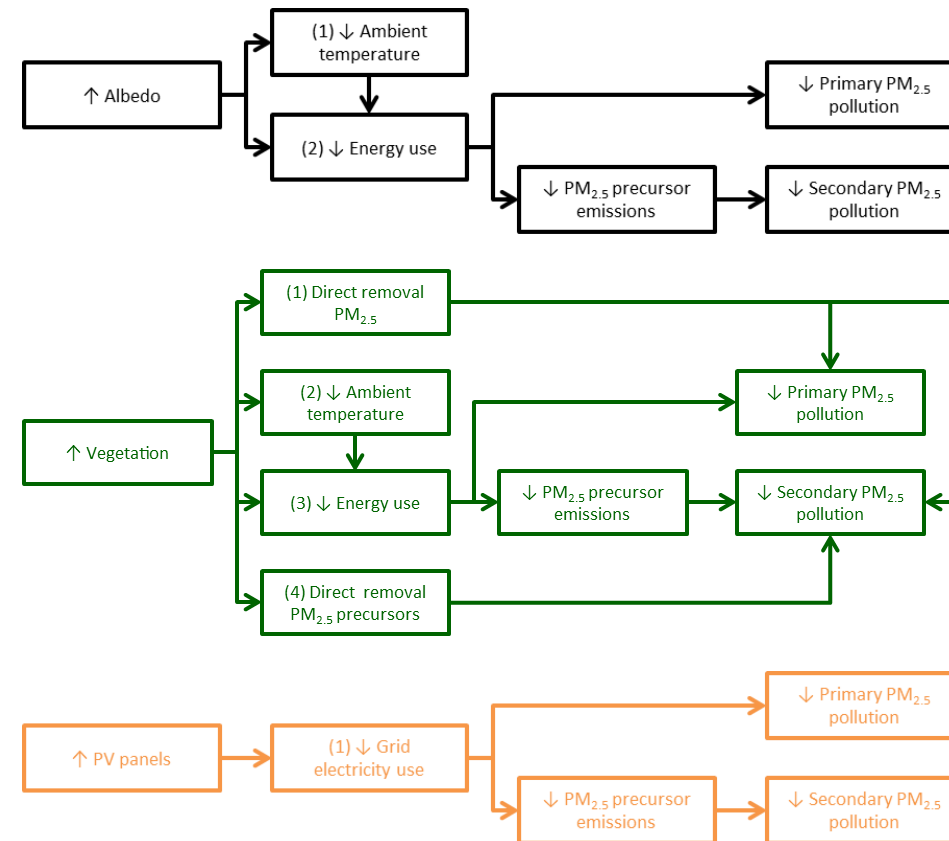
- Electricity generation
  - Offsets electricity purchases from the grid with less expensive electricity generated onsite → lower electricity costs
- Reduced PM<sub>2.5</sub> pollution
  - Reduced incidences of respiratory (e.g., worsened asthma, inflammation) and cardiovascular (e.g., heart disease) health problems and deaths → lower healthcare expenditures
- Reduced GHG emissions
  - Reduced climate change impacts → decreased economic damage due to climate change

# Air pollution reduction pathways

## Ozone



## PM<sub>2.5</sub>



# Key technology assumptions

## Cool roofs

- Cool roof albedo: 0.65 (low slope); 0.4 (steep slope)
- Cool roof life: 20 years
  - Installed at start of 40 year analysis and replaced once (in year 21)
- Installed on low slope and steep slope roofs

## Green roofs

- Growing media depth: 4.5 inches
- Leaf area index: 2
- Green roof life: 40 years
  - Installed at start of 40 year analysis and not replaced
- Installed on low slope roofs only

## Rooftop PV

- PPA term: 20 years
  - Assume two PPAs executed sequentially during 40 year analysis
- PPA savings: 10% off electricity price
- Tilt: 10°
- Azimuth: 180°
  - For simplicity assume only low slope roofs have PV
- Annual degradation: 0.05%



# DGS (as building owner only) costs and benefits (present value \$ per ft<sup>2</sup> of roof)

COMPARISON	Cool compared to Conventional
<b>COSTS</b>	<b>\$0.76</b>
First cost	\$0.34
Operations and maintenance	\$0.23
Additional replacements	\$0.19
<b>BENEFITS</b>	<b>\$1.34</b>
Energy	\$1.34
Direct energy savings	\$1.34
<b>NET TOTAL</b>	<b>\$0.57</b>

COMPARISON	Green compared to Conventional
<b>COSTS</b>	<b>\$22.56</b>
First cost	\$15.00
Stormwater BMP review fee	\$0.11
Operations and maintenance	\$7.45
Additional replacements	\$0.00
<b>BENEFITS</b>	<b>\$55.68</b>
Energy	\$2.07
Direct energy savings	\$2.07
Stormwater	\$53.61
Fee discounts	\$1.14
SRC revenue	\$52.47
<b>NET TOTAL</b>	<b>\$33.12</b>

COMPARISON	Conventional w/ PV (PPA) compared to Conventional
<b>COSTS</b>	<b>\$0.00</b>
<b>BENEFITS</b>	<b>\$5.47</b>
Energy	\$5.47
Energy generation	\$5.47
<b>NET TOTAL</b>	<b>\$5.47</b>

Roof Technology	Cool roof	Green roof (w/o SRCs)
Internal Rate of Return	11%	10% (None)
Simple Payback (years)	9	12 (Never)
Benefit-to-Cost Ratio	1.75	2.47 (0.14)
Net Present Value	\$0.57	\$33.12 (-\$19.35)

# DGS full costs and benefits (present value \$ per ft<sup>2</sup> of roof)

COMPARISON	Cool compared to Conventional	Green compared to Conventional	Conventional w/ PV (PPA) compared to Conventional
<b>COSTS</b>	<b>\$0.76</b>	<b>\$22.56</b>	<b>\$0.00</b>
First cost	\$0.34	\$15.00	\$0.00
Stormwater BMP review fee	N/A	\$0.11	\$0.00
Operations and maintenance	\$0.23	\$7.45	\$0.00
Additional replacements	\$0.19	\$0.00	\$0.00
<b>BENEFITS</b>	<b>\$5.04</b>	<b>\$59.82</b>	<b>\$46.72</b>
<b>Energy</b>	\$1.57	\$2.33	\$5.47
Direct energy savings	\$1.34	\$2.07	N/A
Indirect (UHI) energy savings	\$0.24	\$0.26	N/A
Energy generation	N/A	N/A	\$5.47
<b>Stormwater</b>	N/A	\$53.61	N/A
Fee discounts	N/A	\$1.14	N/A
SRC revenue	N/A	\$52.47	N/A
<b>Health</b>	\$3.28	\$3.51	\$32.56
Ozone	\$1.62	\$1.52	N/A
PM2.5	\$1.05	\$1.39	\$32.56
Heat-related mortality	\$0.61	\$0.61	N/A
Climate change	\$0.19	\$0.37	\$8.69
<b>NET TOTAL</b>	<b>\$4.28</b>	<b>\$37.26</b>	<b>\$46.72</b>

Roof Technology	Cool roof	Green roof	Rooftop PV
Internal Rate of Return	58%	11%	N/A
Simple Payback (years)	2	11	N/A
Benefit-to-Cost Ratio	6.62	2.65	N/A
Net Present Value	\$4.28	\$37.26	\$46.72

# Total present value of costs and benefits for all low slope (incl. flat) DGS roofs

COMPARISON	Cool compared to Conventional	Green compared to Conventional	Conventional w/ PV (PPA) compared to Conventional
<b>COSTS</b>	<b>\$5,580,000</b>	<b>\$203,000,000</b>	<b>\$0</b>
<b>BENEFITS</b>	<b>\$52,100,000</b>	<b>\$538,000,000</b>	<b>\$294,000,000</b>
<u>Energy</u>	\$17,100,000	\$21,000,000	\$34,500,000
<u>Stormwater</u>	N/A	\$482,000,000	N/A
<u>Health</u>	\$32,900,000	\$31,600,000	\$205,000,000
<u>Climate change</u>	\$2,110,000	\$3,310,000	\$54,700,000
<b>NET TOTAL</b>	<b>\$46,500,000</b>	<b>\$335,000,000</b>	<b>\$294,000,000</b>

Roof technology	Internal Rate of Return	Simple Payback Period (years)
Cool roof	91%	2
Green roof	11%	11
PV (PPA)	N/A	N/A

# Benefit and cost model sources include:

- Health
  - Li et al., 2014
    - Temperature reduction used in ozone analysis
  - Bloomer et al., 2009
    - Temperature-ozone relationship
  - Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE)
    - Ozone health impact and benefit valuation; developed by EPA
  - Machol and Rizk, 2013
    - PM<sub>2.5</sub> benefit valuation
  - Kalkstein et al., 2013
    - Temperature reduction used in heat-related mortality analysis
    - Heat-related mortality impact
- Climate change
  - Pepco emissions data
  - Social cost of carbon (SCC) – U.S. Federal Gov't
- Energy
  - Green Roof Energy Calculator (GREC)
    - Direct energy for cool and green roofs
  - Cool Roof Energy Savings Tool (CREST)
    - Direct energy for cool roofs
  - Akbari and Konopacki, 2005
    - Indirect energy for cool and green roofs
  - PVWatts Calculator
    - Direct energy for rooftop PV
- Stormwater
  - Stormwater Fee – DDOE
  - Impervious Area Charge (IAC) – DC Water
  - Stormwater Retention Credits (SRCs) – DDOE

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For the full report visit [Capital E's website](#).