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Real Results.

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Environmentally Beneficial Paving Additives Using TiO2

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IMPACTS AND BENEFITS FROM PAVEMENT PRESERVATION

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MICHIGAN STATE UNIVERSITY

AASHTO TSP2 PAVEMENT PRESERVATION

ROCKY MOUNTAIN WEST PAVEMENT PRESERVATION PARTNERSHIP
SOUTHEAST PAVEMENT PRESERVATION PARTNERSHIP
MIDWESTERN PAVEMENT PRESERVATION PARTNERSHIP
NORTHEAST PAVEMENT PRESERVATION PARTNERSHIP

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Pavement Preservation & Environmental Sustainability Specialists

- ~50,000 Miles
- $6.3 Billion in Carbon Value*
- $3.1 Billion in Agency Budget Savings

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Doubling Pavement Life

Molecular Rejuvenation Pioneers

Figure 5 – Maltene Rejuvenator (Reclamite) Study:
Eight Year Oxidation Rate Curves Charleston County (SC) [38] (in poises) [39]

Source: Pavement Technology, Inc.; APART

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World's First Retrofit Photocatalytic Technology for Pavements to Target Use Phase Emissions

Traditional Pavement Preservation Agents
Fortified with Photocatalytic Grade TiO_2

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Why Did We Develop Photocatalytic Solutions?

To Solve The Next Problems Facing Transportation Professionals

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Environmental Product Declarations

EPD Headwinds or Opportunity for Paving Industry?

- FHWA to Release EPD Guidelines
- EO-14057(S303) USDOT Buy Clean Initiative
- H.R. 3684 Infrastructure Investment Act (IIJA)
- H.R. 5376 Inflation Reduction Act (IRA)
- State DOT EPD Adoption Rapidly Coming
- “FAST” Act | CMAQ

CO_2e Reduction Options in Paving

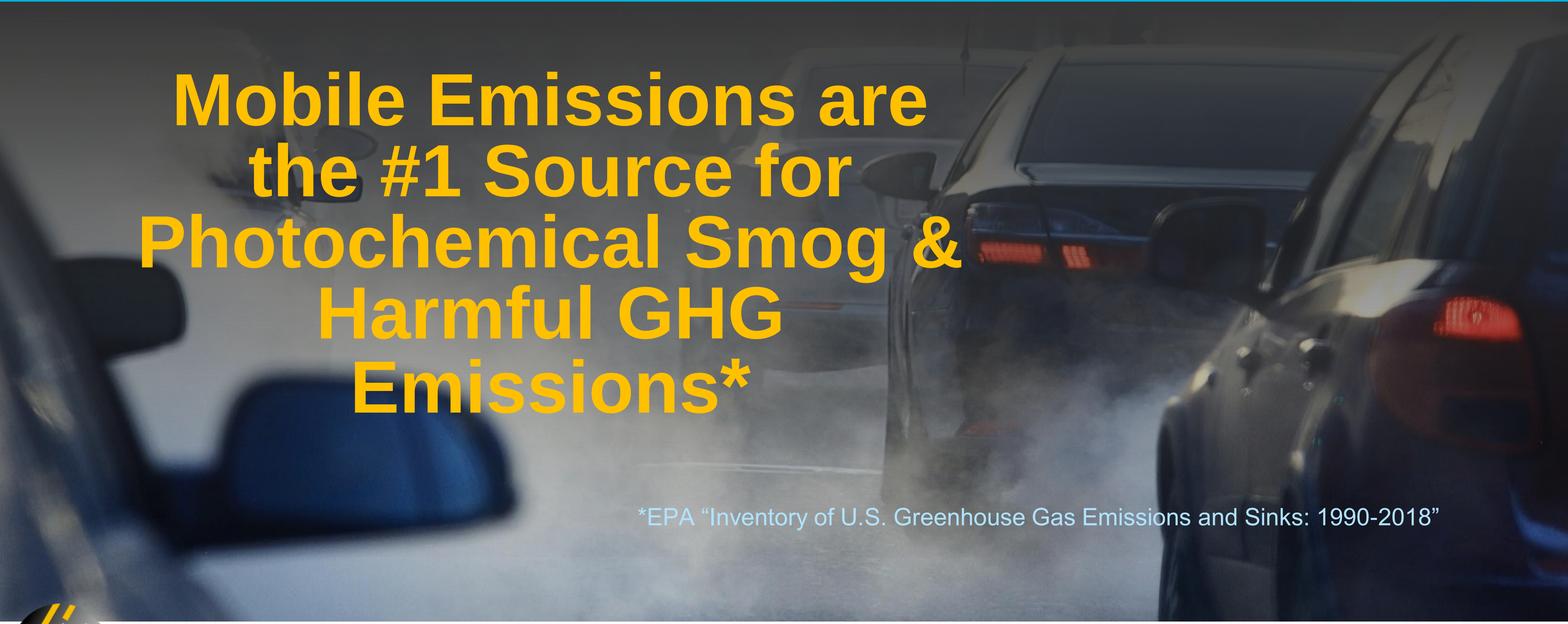
- **Embodied Carbon Reductions Difficult**
- **Use Phase Technologies Will Be Needed**

Use Phase – System Boundaries

- Carbonation | Sequestration
- Pavement Vehicle Interactions (PVI)
- Albedo | Emissivity | Urban Heat Island
- Waterways

"To achieve net zero in the production of asphalt mixtures, carbon offsets will be necessary" – NAPA *The Road Forward*

Big Targets



Mobile Emissions are the #1 Source for Photochemical Smog & Harmful GHG Emissions*

*EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018"

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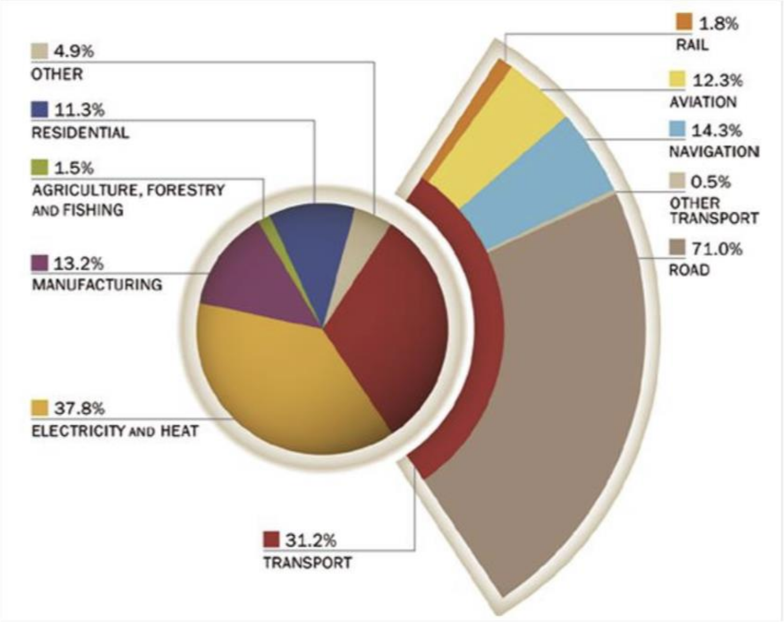
Carbon Emissions



26%

Roads & Airfields

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Excessive Heat #1 Weather-Related Killer*

Pavements One-Third of Urban Heat Sinks

*National Weather Service

85% of Microplastic Air and Waterway Pollution from Tires and Brake Pads*

*Carrington, "Airborne Plastic Pollution 'Spiraling Around the Globe," *The Guardian*, 2020

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***7 Million Metric Tons Annually**

Brakes & Tires

30% PM 2.5

82% Goes in Our Water

*EPA

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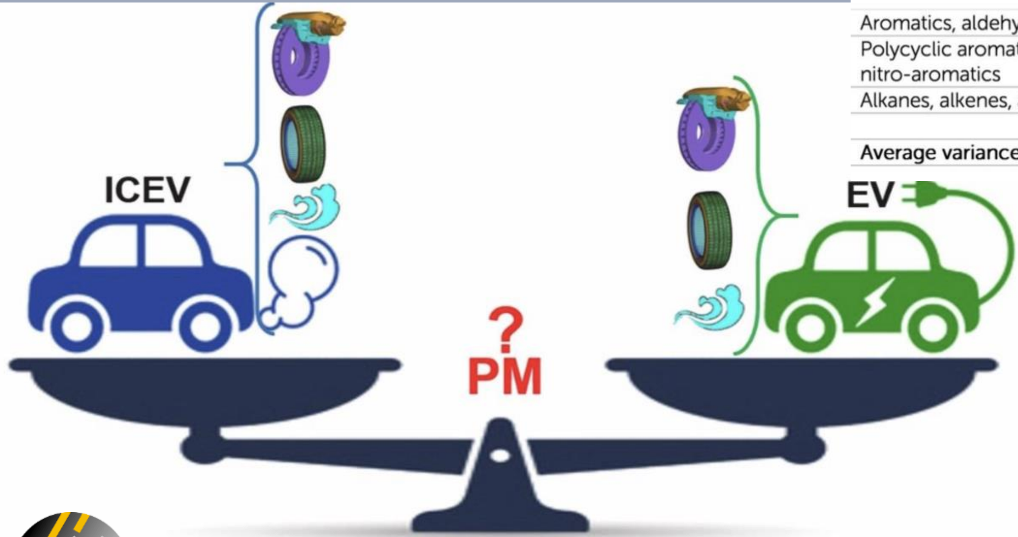
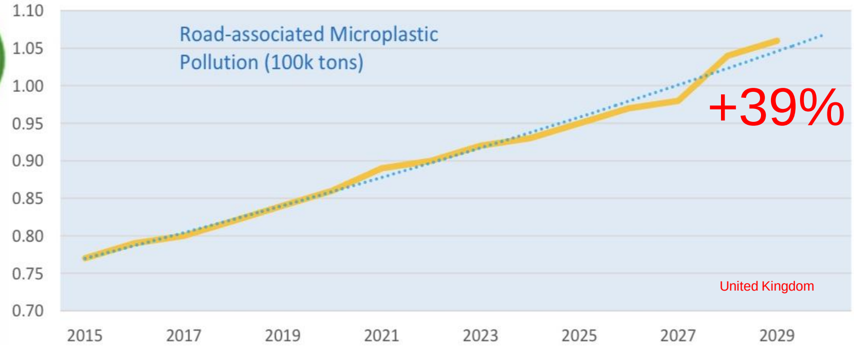
EVs Increase On-Road Tire Pollution

Emission type, mg, d8-toluene equivalence basis	Kia Niro – tailpipe	Kia Niro – tyres	Tesla Model Y – tyres	Kia Niro total vs Tesla Model Y
Aromatics, aldehydes, ketones	1.86	54.26	150.52	-63%
Polycyclic aromatic hydrocarbons, nitro-aromatics	0.32	90.21	487.83	-82%
Alkanes, alkenes, alkynes, cyclo	2.20	185.41	255.50	-27%
Average variance				-57%





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How & How Well Do Photocatalytic Solutions Work?

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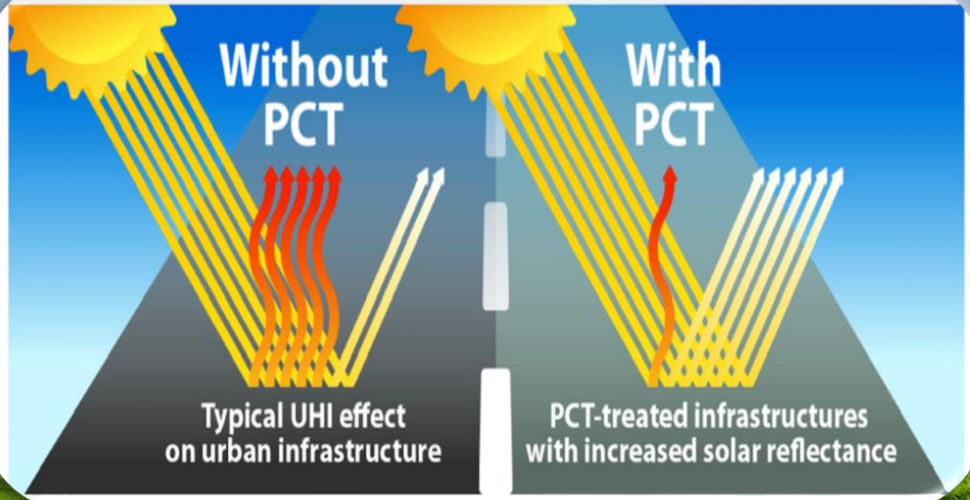
TiO_2 is Photoreactive

Consumes & Redirects UV Light



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Proven to Reduce Exhaust Emissions by as much as 60% & NEE's by 98%

CO_2
NOx
VOCs
Microplastics

Invisible Pollution Scrubbing Subway

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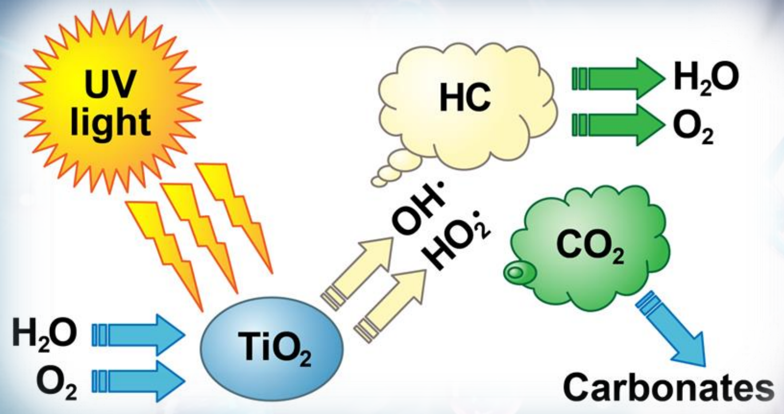
Photocatalytic Decarbonization



$CaCO_3$ / CO_3

Natural Reduction by Oxidation or Redox

100% Perpetual

Solar Powered Carbon Removal

CO_2 Capture & Decomposition

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(Super)Natural Concrete Carbon Sinks

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Preliminary conclusions
(10-week)

VELAY Research group

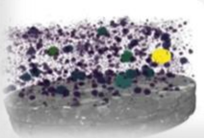
- Results showed that using the product **TiIntroCME® on Portland cement concrete pavements (PCCP) increased the CO_2 removal** at all application rates studied, **reducing up to 34% of the CO_2 concentration** in the ambient.

PURDUE UNIVERSITY College of Engineering

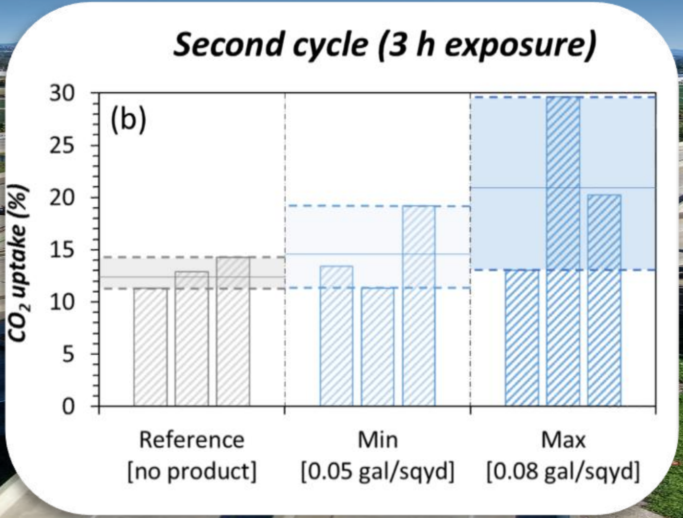
VELAY Research group

Nanomodification & CO_2 capture

CONCLUSIONS:



Nanomodification of the concrete's matrix microstructure can enable us to **double the natural CO_2 capture** rate.



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Perpetual Carbon Sink Research

THE PERSISTENT PURSUIT OF THE
NEXT GIANT LEAP

NEIL ARMSTRONG HALL OF ENGINEERING

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achieve a remarkable 41.81% reduction in CO_2 concentration. This corresponds to a substantial enhancement in the material's CO_2 reduction capabilities when employing TiIntroCME®.

application of the product, as well as an increase in the overall CO_2 uptake. This means that as time goes by, the samples are still being able to absorb and/or decompose CO_2 from the air, which is preferable, as it the material will potentially keep reducing the CO_2 concentration in the air, without reaching a plateau.

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How We Spent Our Summer Vacation

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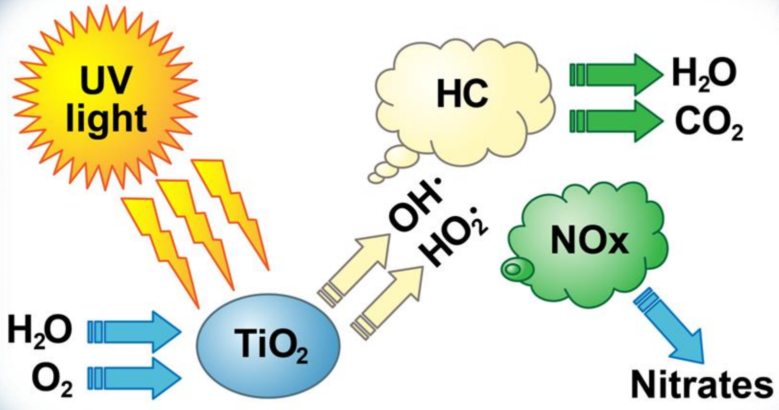
Smog Eating



Oxidative Removal of NO_2 and VOCs

850x as Toxic When Airborne

NOx Capture & Decomposition

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TiO_2 Virtually Eliminates RAMPs!

Sample	Microplastic Reduction Efficiency				
	Test (hours)	Pled (watts)	Diameter Beg	Diameter End	Volume Loss
A	2	110	100nm	37nm	94.8%
B	24	110	100nm	16nm	99.6%

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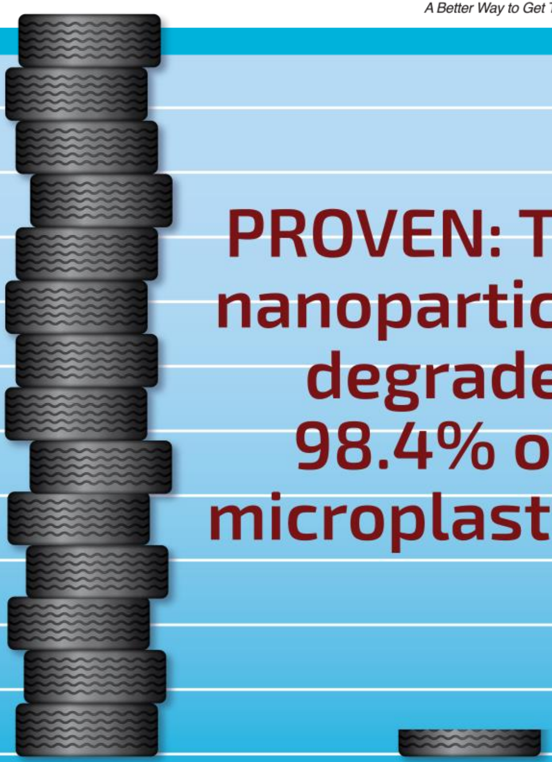
PROVEN: TiO_2 nanoparticles degrade 98.4% of microplastics*



Without TiO_2
100%

With TiO_2
1.6%

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EFFECT OF TiO_2 TOPICAL TREATMENTS ON CONCRETE AND ASPHALT FOR ON-ROAD MICROPLASTIC POLLUTANT REMOVAL

Conclusion:

The images taken with the SEM are direct evidence of the rapid and substantial evaporation of microplastics with the aid of TiO2 as a catalyst. Several samples were successfully tested and analyzed resulting in a substantial volume loss over time (specifically a change in microsphere diameter).

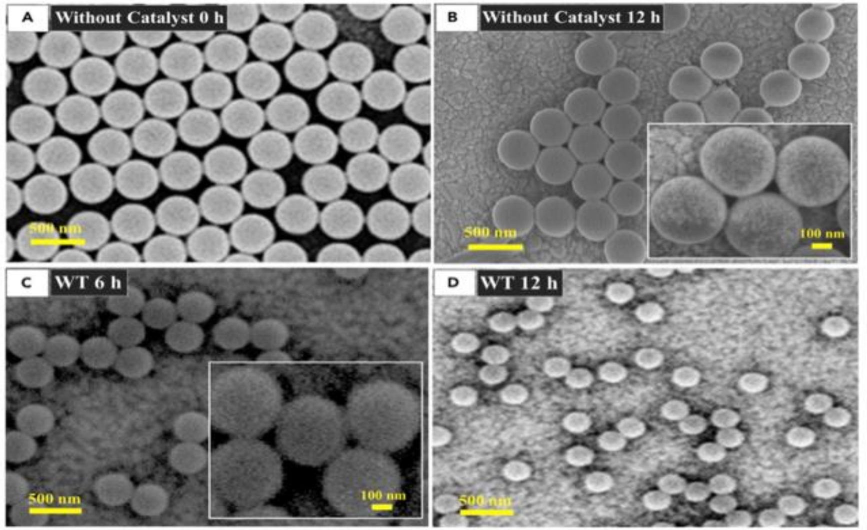
Results:

The twenty-four (24) hour volume loss found in each sample can be found in Table [1]. This volume loss represents the smallest diameter found in the SEM images per sample. There is evidence of 100% volume loss in the SEM images which can be observed in the right most picture in Figure [1] and more easily in Figure [2].

Table 1: 24 – Hour Irradiation

Sample #	Test Duration (hrs)	P_{LED} (W)	$D_{initial}$ (nm)	D_{final} (nm)	$V_{initial}$ (nm^3)	V_{final} (nm^3)	Volume Loss (%)
1	2	110	100.0	37.4	523599	27282	94.8
2	24	110	100.0	15.7	523599	2026	99.6

SEM Images



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Use Phase Redox Technology Benefits

- ✓ MRT saves 1,500 tons AC CO_2e per CLM per Cycle
- ✓ TiO_2 doubles concrete carbon uptake to 50%+ & is perpetual
- ✓ TiO_2 removes >6,000 CO2e per CLM per year
- ✓ TiO_2 removes 98% of Road-Associated Microplastic Pollutants
- ✓ TiO_2 removes up to 60% of Tailpipe Emissions
- ✓ TiO_2 improves Solar Reflectance 4x Asphalt | 2x Concrete

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Preservation Benefits of TiO2

- ✓ TiO_2 accelerates and doubles concrete durability ($CaCO_3$)
- ✓ TiO_2 quadruples Asphalt UV protection (solar reflectance)
- ✓ TiO_2 improves pavement permeability (5x water contact angle)

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Field Application

Penetrant-based to Achieve Both Durability and Affordability

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Sustainable

Penetration is Key

Orlando International Airport

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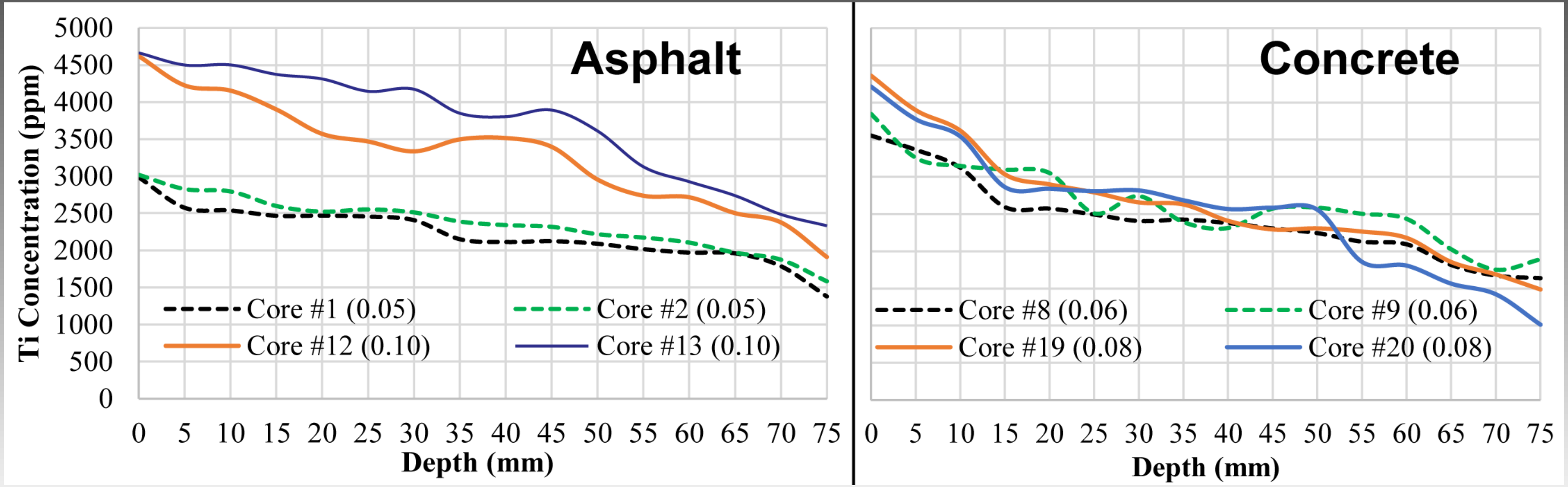

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Sustainable

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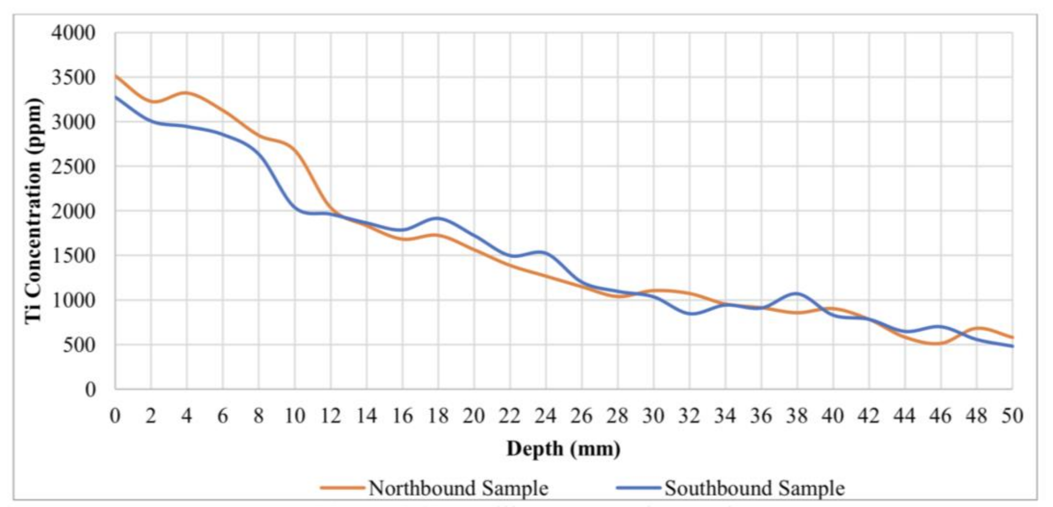
Sustainable

88% Retention Post Five Years

Greenville



Tailpipe Emissions

Raleigh

NO Reduction Efficiency (%)*				
A.R.A.-1 Ti®	0.04 + 0.03 gsy	0.04 gsy	0.06 + 0.03 gsy	0.06 gsy
	47%	38%	50%	43%

Cincinnati

NO Reduction Efficiency (%)*				
A.R.A.-1 Ti®	0.08 gsy	0.08 gsy	0.07 gsy	0.07 gsy
	46%	45%	42%	44%

*ISO 22197-1 Photocatalytic Materials Air Purification Test Procedure

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Urban Heat Islands

Orlando

Compound / Substrate	Solar Reflectance Index Values (SRI)					
	Control Sample	Control Sample	0.10 gsy	0.10 gsy	0.08 gsy	0.08 gsy
A.R.A.-1 Ti®/ Asphalt	9	8	40	39		
Litho1000 Ti®/ Concrete	24	24			38	38

Charlotte

Compound / Substrate	Solar Reflectance Index Values (SRI)				
	Control Sample	0.05 gsy	0.05 gsy	0.07 gsy	0.07 gsy
A.R.A.-1 Ti®/ Asphalt	9	34	34	40	39

*ASTM E1980-11: Solar Reflectance Index

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Thermal Imagery

Raleigh

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Phoenix

	Control	Core #1	Core #2	Core #3
Reflectance	8	42	43	40
Tailpipe Emissions	0%	48%	51%	46%

Tucson

	Control	Core #1	Core #2
Reflectance	7	44	45
Tailpipe Emissions	0%	53%	54%

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Self Cleaning

The Oxidizing Power of TiO_2

- ✓ Anti-Nitrogen and Carbon
- ✓ Anti-Trace Gases
- ✓ Anti-Plastic
- ✓ Anti-Mold
- ✓ Antimicrobial
- ✓ Anti-Graffiti

Carbon Accounting

PlusTi EPDs Coming Winter 23-24

Direct Carbon Reduction at Scale

One Mile TiO_2-Treated Road Equals

Fifteen Acres of Forest

>6,000 Metric Tons CO_2e per Year*

Pollution Generated by ~1,000 Cars!

*25,000 AADT

Table 18 – Tree Equivalence of a Photocatalytic Surface

Urban street tree	Photocatalytic surface		Photocatalytic surface	Urban street tree
10	(100 – 125) m^2		10 m^2	0.8 – 1
1,000	(10,000 – 12,500) m^2		1,000 m^2	80 – 100
5,000	(50,000 – 62,500) m^2		5,000 m^2	400 – 500

Source: HeidelbergCement Group

~Each Mile of Road

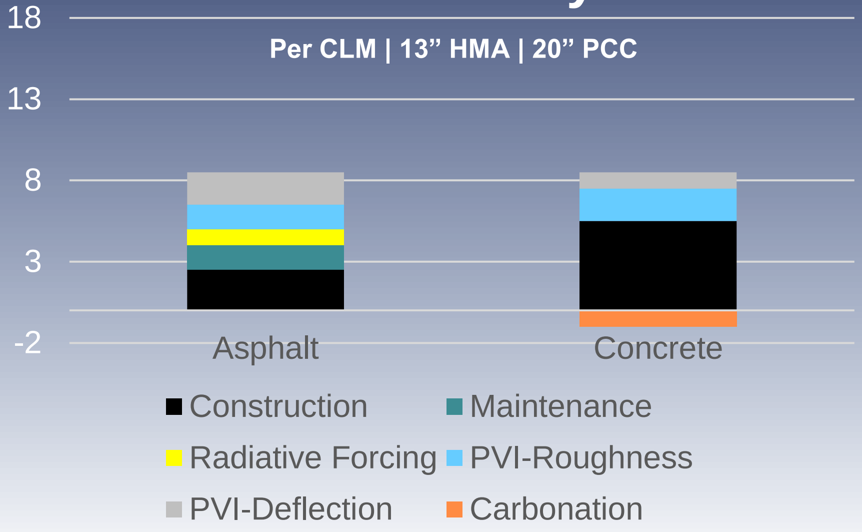
Table 19 – Car Equivalence of a Photocatalytic Surface

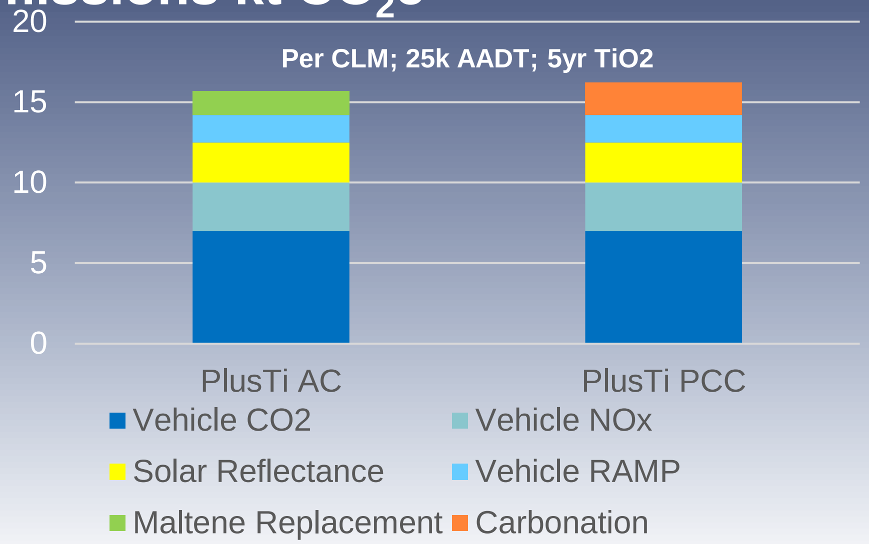
Gasoline car (Euro 6)	Photocatalytic surface (needed to eliminate the corresponding emissions)
1	(46 – 57) m^2
10	(460 – 570) m^2
1,000	(46,000 – 57,000) m^2

Source: HeidelbergCement Group

Negative Carbon Road Systems

Lifecycle GHG Emissions kt CO_2e





Source: MIT CSHub; BlackwallPartners LLC

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The Scalable Photocatalytic Pavement Solution

- ✓ Orlando
- ✓ Delray Beach FL
- ✓ Raleigh
- ✓ Charlotte
- ✓ Durham
- ✓ Cary NC
- ✓ Greenville SC
- ✓ Charleston
- ✓ Greater Cleveland
- ✓ Cincinnati
- ✓ Phoenix
- ✓ Tucson
- ✓ Tempe
- ✓ FHWA 'Climate Challenge' Grant (Purdue)
- ✓ Orlando Intl Airport
- ✓ Vero Beach Reg Airport
- ✓ Austin
- ✓ San Antonio
- ✓ Edina MN (MnRoads)
- ✓ Nevada DOT
- ✓ Avondale AZ
- ✓ Yellowstone Nat Park

Environmental Justice

Pavement Owners Have a Unique Opportunity!

- Roads are Everywhere Impacting Every Community
- Heat; Smog; Carbon; Water

Cost

<5% Added Paving Cost

<$20,000 per mile

<\$2 CO_2 per ton

~\$1 CO_2e per ton

Road System Photocatalysis

- Existing Roads = No New Land Use
- TiO_2 x Sunlight = "Free Energy"
- CO_2e Comes to Us
- Huge Environmental & Ecological Gains
  - Accelerates Carbon, Nitrogen and Plastic Cycles
  - Reducing Dangerous Airborne & Waterborne Pollution
- Full Uptake = No Dumping!

Table 25 – Cost of Carbon Removal

	Est. Cost Per Ton ($)
Direct Air Capture	>1,000
Rock Mineralization	>500
Biden Administration	125-190
Lower Carbon Portland Cement	75-125
Paris Agreement (2030)	100
Lower Carbon Steel & Iron	50-100
Renewable Energy	50-100
Carbon ETF	45
Biofuel	30-40
Nat Gas for Coal	<20
Photocatalytic Pavement	<2

Source: EPA; IEA; Verra; HIS Markit; et al


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Congratulations Charleston!

2023 APWA Technical Innovation Award

Charleston County Public Works Titanium Dioxide Program

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Resources

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www.SmogEatingRoads.com