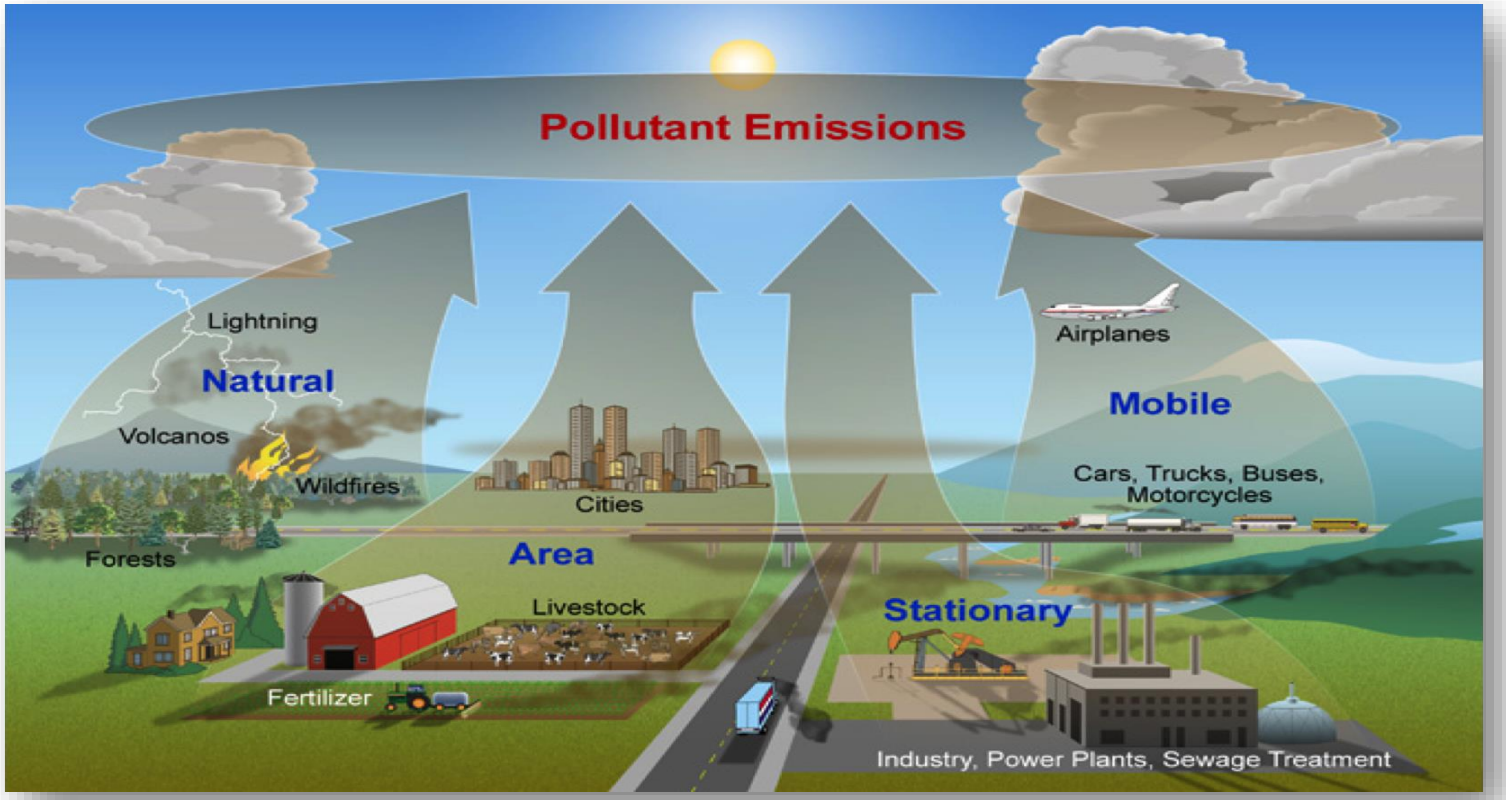
Remediating Mobile Source Pollution

with

Photocatalytic Pavements

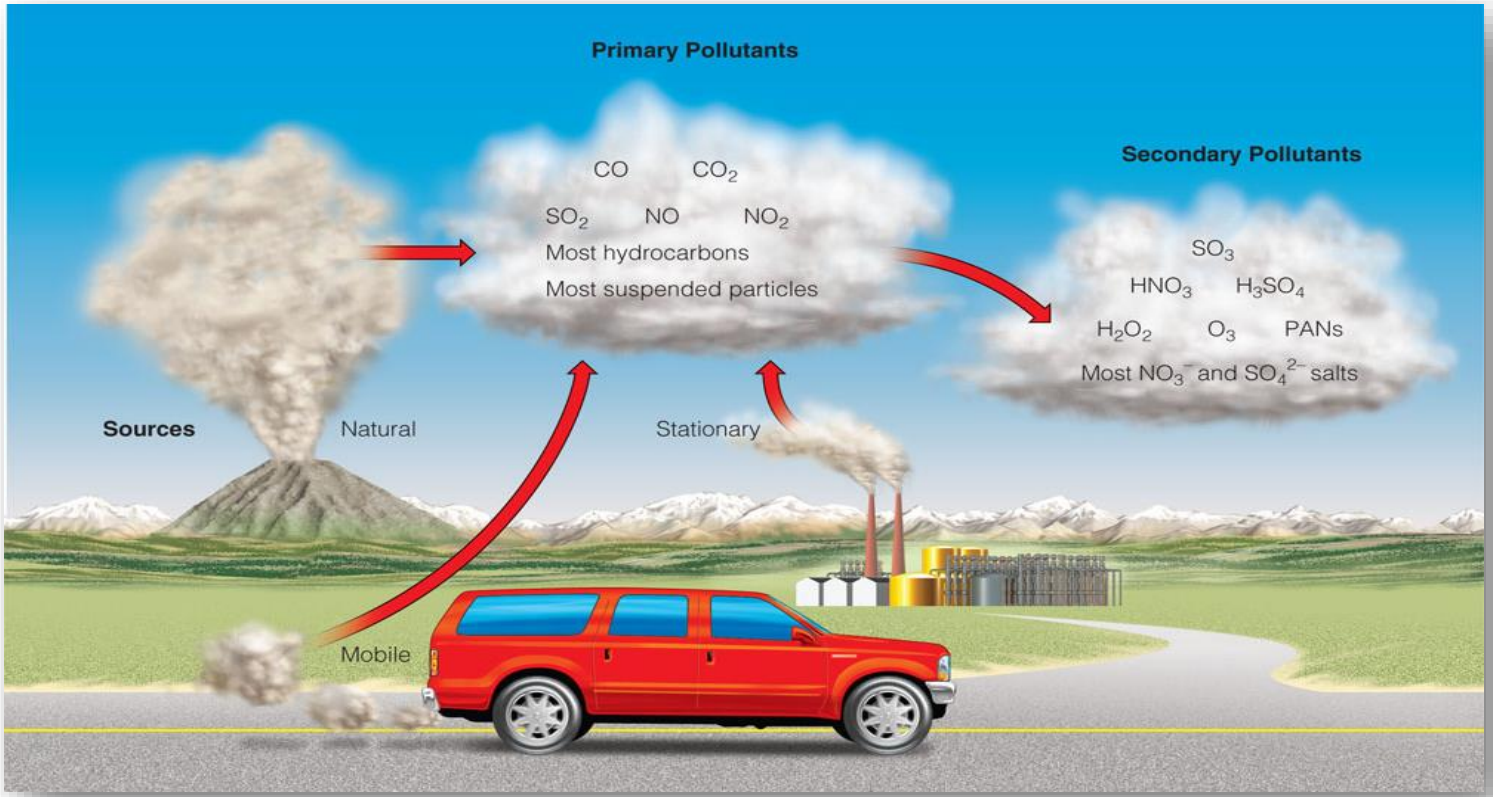
Michael Durante
Vice President
Finance & Strategic Planning
mdurante@pavetechinc.com

Air Pollution



A Serious Problem

From the Vehicles we drive...
to the Air We Breathe



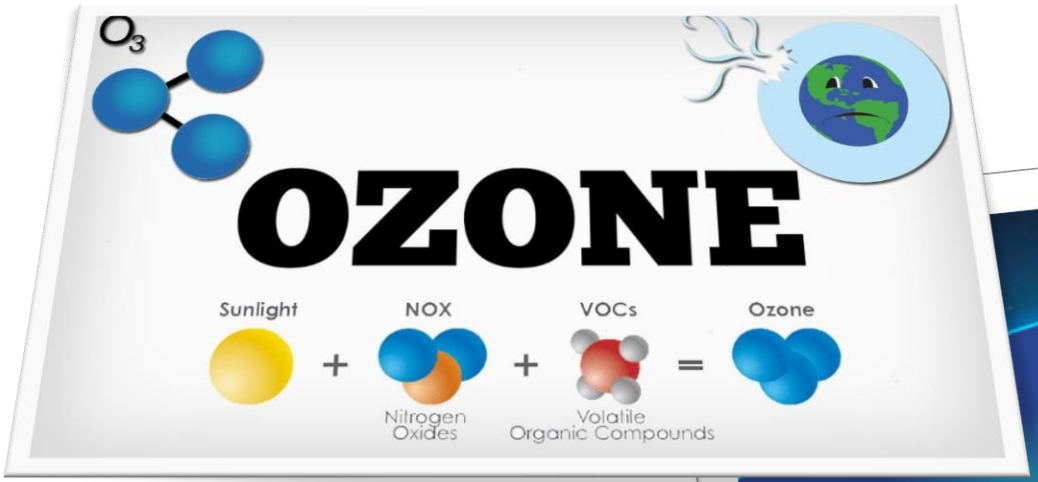
Climate vs. Ozone

Greenhouse Gases

CO_2 Prime Contributor to 'Global Warming' Effect

NO_x Major Cause of Ground Level Air Pollution

Ground Level Pollution




PAVEMENT TECHNOLOGY INC.
SINCE 1972
Real Science. Real Results.

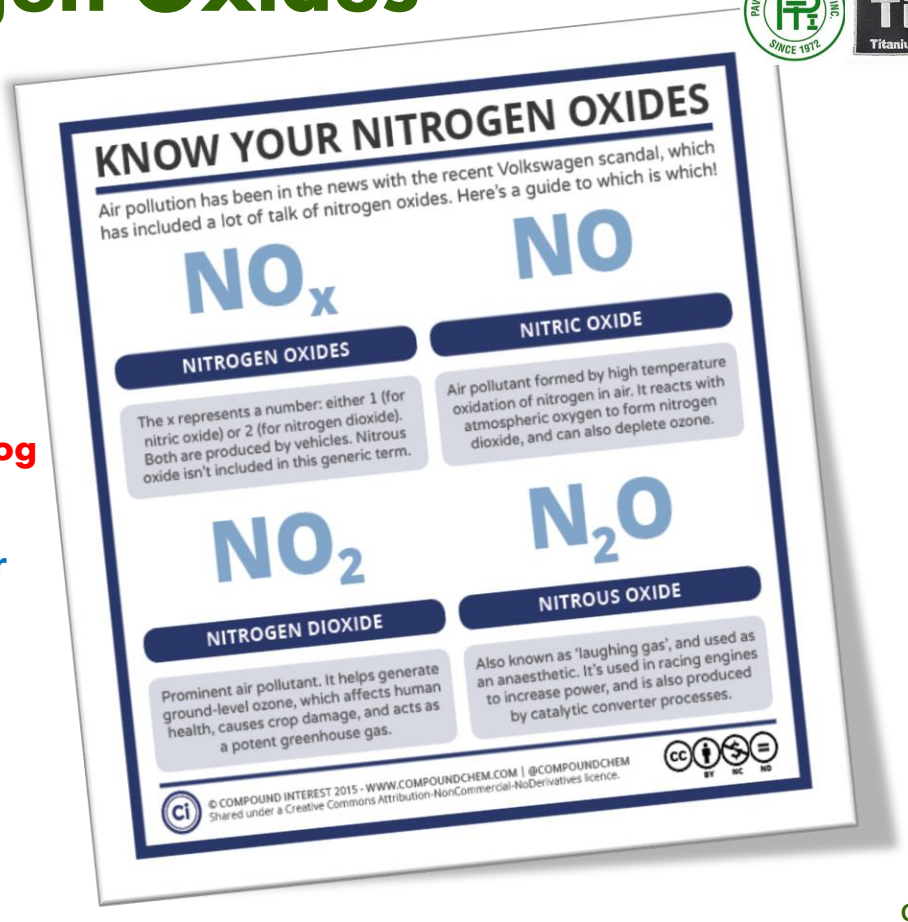

22
47.90
Ti
Titanium

Nitrogen Oxides

Mobile Source Emissions 80% of Smog and 45% of Total GHGs [1]

Combustion of Nitrogen and Oxygen
Caused by fuel *igniting* in car engine

- ✓ **Toxic to Humans**
- ✓ **Major Contributor to Photochemical Smog**
- ✓ **Major Contributor to Acid Rain**
- ✓ **Damaging to Stratospheric Ozone Layer**



---

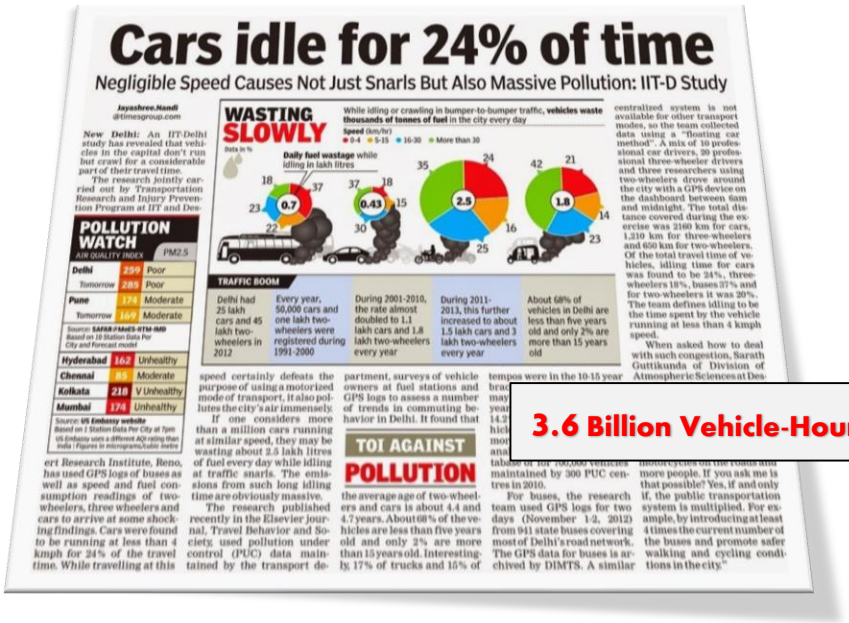
[1] **Environmental Protection Agency; Stanford University, School of Earth, Energy & Environmental Sciences; Vanderbilt University, Climate Change Research Network.**

Ozone Crisis

Oxides of Nitrogen 300x as Toxic as Carbon Dioxide (CO_2e)[1]

385 million equivalent metric tons NO_x[1]

45% of Americans Exposed to 'Near-Roadway' Pollution[2]



Cars idle for 24% of time

Negligible Speed Causes Not Just Snarls But Also Massive Pollution: IIT-D Study

Jayashree.Nandi @timesgroup.com

New Delhi: An IIT-Delhi study has revealed that vehicles in the capital don't run but crawl for a considerable part of their travel time.

The research jointly carried out by Transportation Research and Injury Prevention Program at IIT and Department, surveys of vehicle owners at fuel stations and GPS logs to assess a number of trends in commuting behavior in Delhi. It found that the average age of two-wheelers and cars is about 4.4 and 4.7 years. About 68% of the vehicles are less than five years old and only 2% are more than 15 years old. Interestingly, 17% of trucks and 15% of tempos were in the 10-15 year

WASTING SLOWLY

While idling or crawling in bumper-to-bumper traffic, vehicles waste thousands of tonnes of fuel in the city every day

Speed (km/hr) 0-4 5-15 16-30 More than 30

Daily fuel wastage while idling in lakh litres

0.7 0.43 2.5 1.8

POLLUTION WATCH

AIR QUALITY INDEX PM2.5

Delhi	259	Poor
Tomorrow	285	Poor
Pune	171	Moderate
Tomorrow	169	Moderate
Hyderabad	162	Unhealthy
Chennai	86	Moderate
Kolkata	218	V Unhealthy
Mumbai	174	Unhealthy

TRAFFIC BOOM

Delhi had 25 lakh cars and 45 lakh two-wheelers in 2012

Every year, 50,000 cars and one lakh two-wheelers were registered during 1991-2000

During 2001-2010, the rate almost doubled to 1.1 lakh cars and 1.8 lakh two-wheelers every year

During 2011-2013, this further increased to about 1.5 lakh cars and 3 lakh two-wheelers every year

About 68% of vehicles in Delhi are less than five years old and only 2% are more than 15 years old

TOI AGAINST POLLUTION

speed certainly defeats the purpose of using a motorized mode of transport, it also pollutes the city's air immensely.

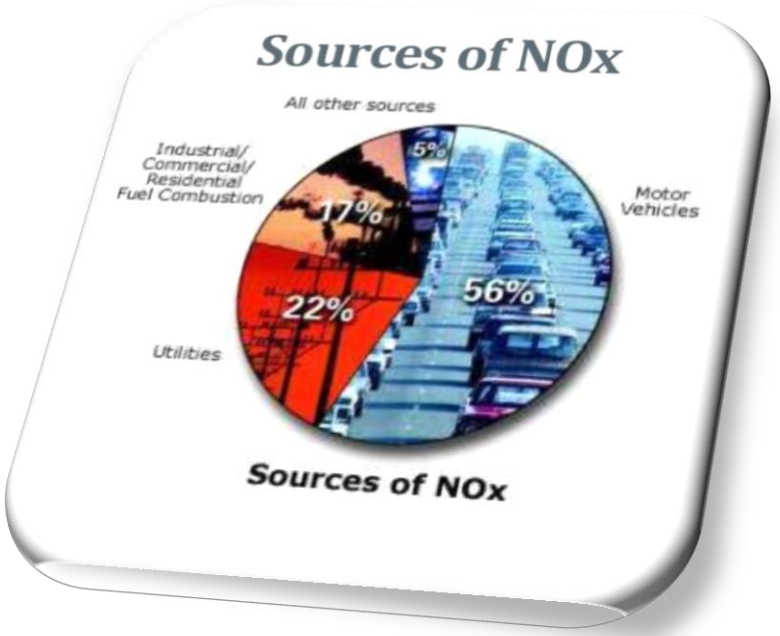
If one considers more than a million cars running at similar speed, they may be wasting about 2.5 lakh litres of fuel every day while idling at traffic snarls. The emissions from such long idling time are obviously massive.

The research published recently in the Elsevier journal, Travel Behavior and Society, used pollution under control (PUC) data maintained by the transport de-

centralized system is not available for other transport modes, so the team collected data using a "floating car method". A mix of 10 professional car drivers, 20 professional three-wheeler drivers and three researchers using two-wheelers drove around the city with a GPS device on the dashboard between 6am and midnight. The total distance covered during the exercise was 2160 km for cars, 1,210 km for three-wheelers and 650 km for two-wheelers. Of the total travel time of vehicles, idling time for cars was found to be 24%, three-wheelers 18%, buses 37% and for two-wheelers it was 20%. The team defines idling to be the time spent by the vehicle running at less than 4 kmph speed.

When asked how to deal with such congestion, Sarath Guttikunda of Division of Atmospheric Sciences at Des-

3.6 Billion Vehicle-Hours[3]



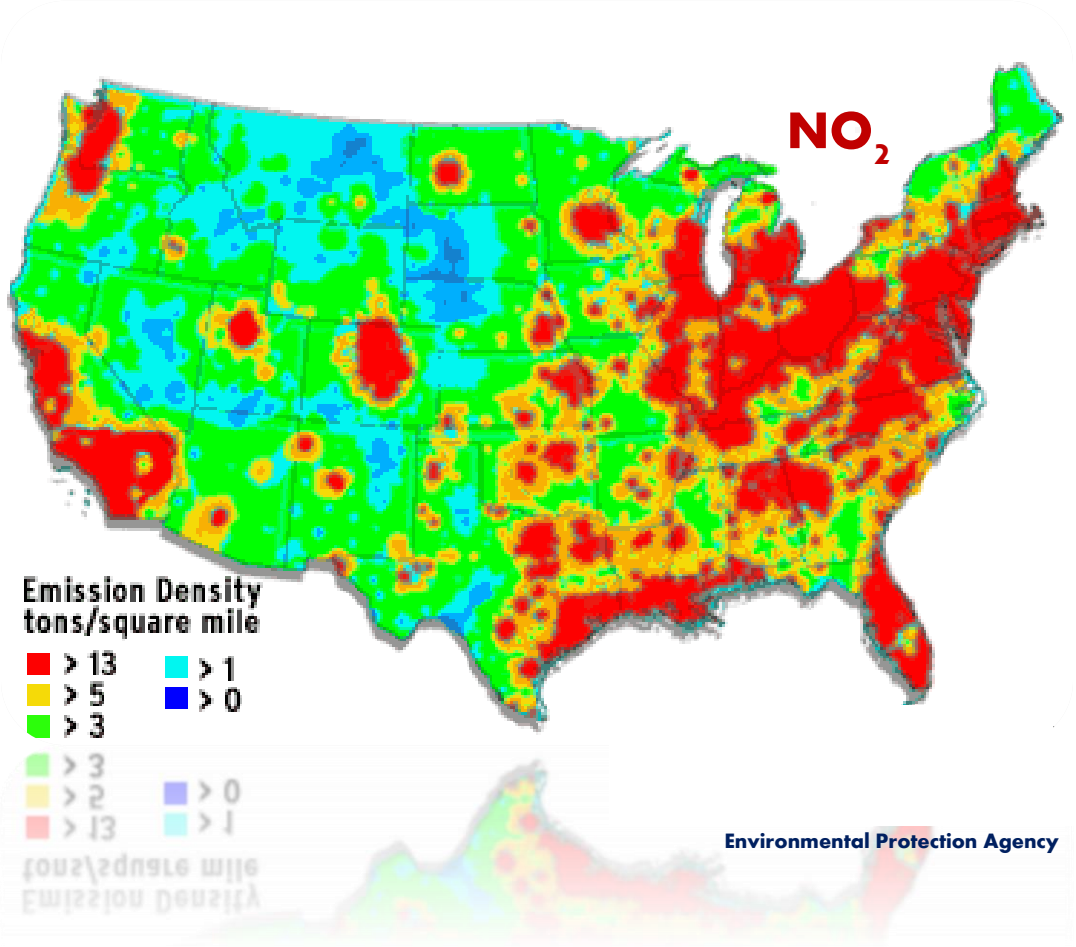
---

[1] One ton of Nitrous Oxide equals 298 tons of Carbon Dioxide equivalent: Environmental Protection Agency.

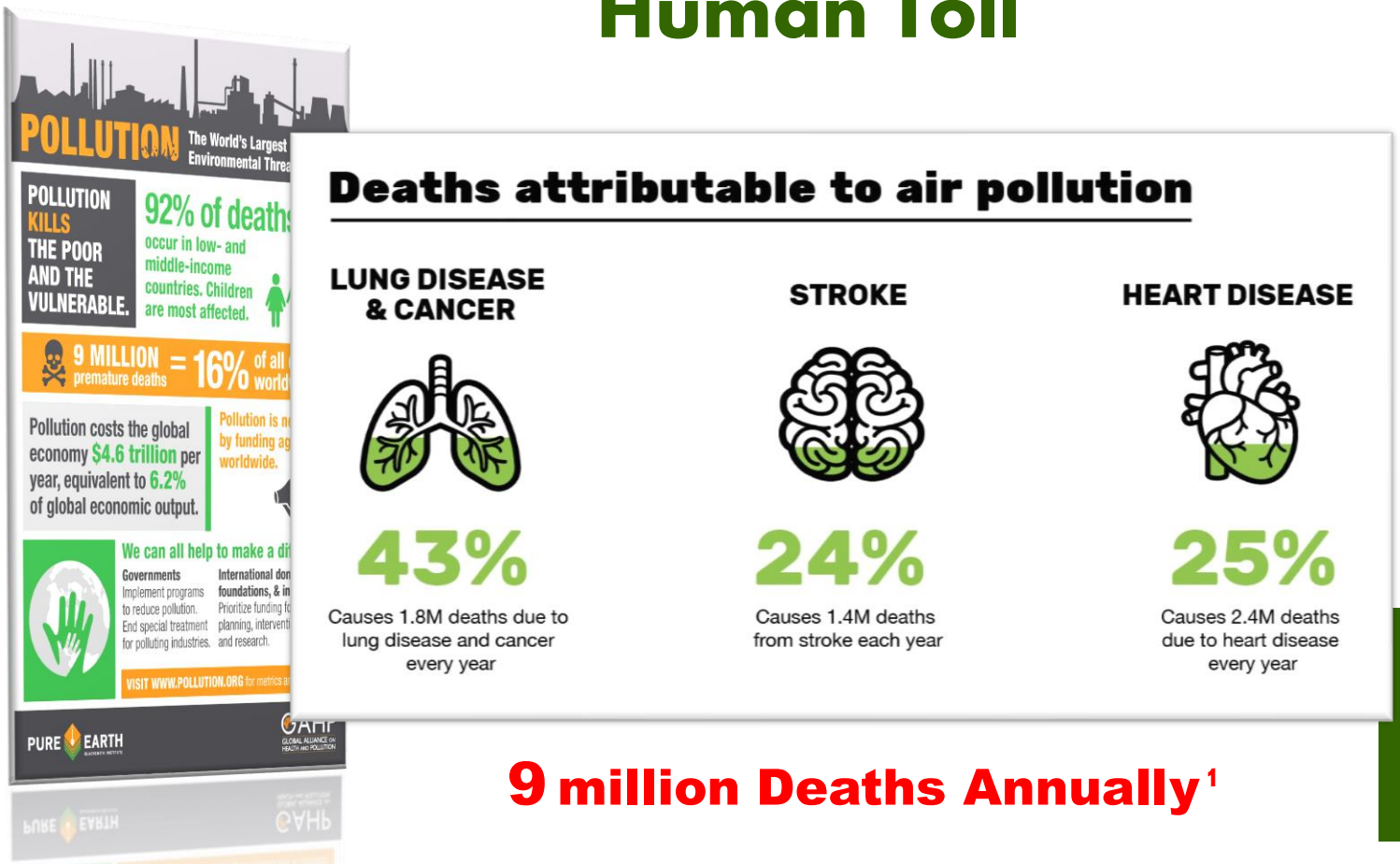
[2] U.S. Census Blocks (2010) within 500 meters of 'High Volume' roads by AADT: U.S. Department of Transportation; Health Effects Institute, Boston, 2010.

[3] Texas A&M Transportation Institute, 2000.

NO_x Density


NO2
Emission Density
tons/square mile
> 13
> 5
> 3
> 1
> 0
Environmental Protection Agency

Human Toll



One in Four American Kids has Asthma

38% Caused by Pollution

9 million Deaths Annually[1]

---

[1]The Climate Reality Project; World Health Organization; Climate and Clean Air Coalition; Global Alliance on Health and Pollution; and Environmental Defense Fund.

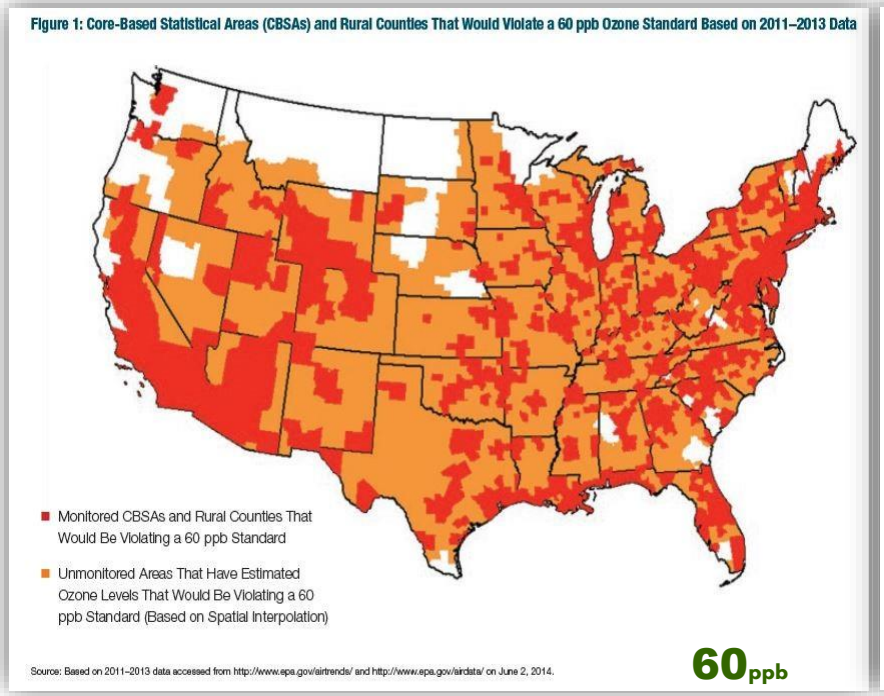
Massive Costs

$4.6 trillion or 6% of Global GDP[1]

---

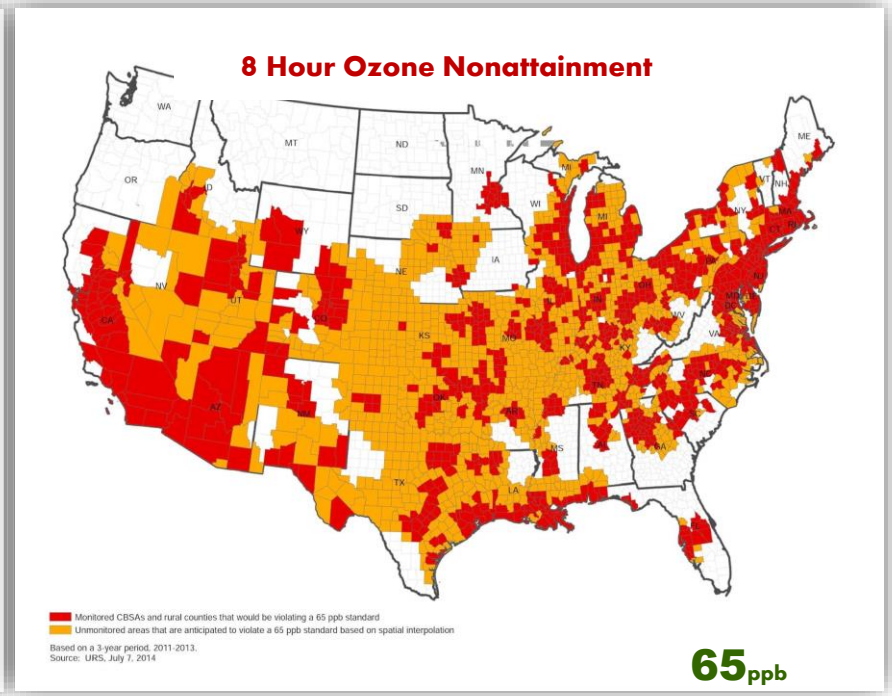
[1]**NYU Langone Medical Center; European Environment Agency; Carnegie Mellon University; and Global Alliance on Health and Pollution.**

Ozone Nonattainment



60ppb

Expected Limit



65ppb

Current Limit

Environmental Protection Agency projections

The Local News

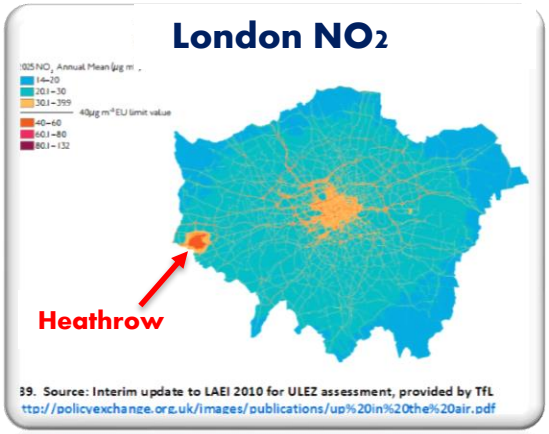
Airports

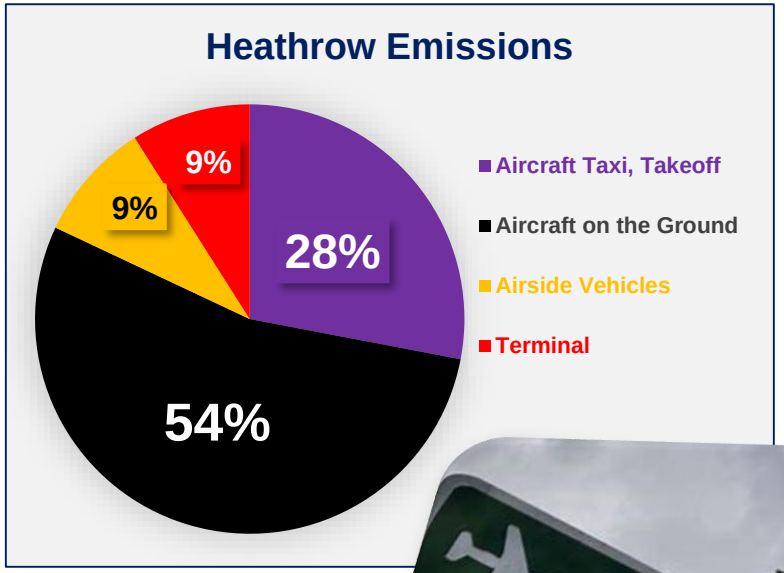
The Economist

Problem in the air

Heathrow's third runway could be blown off course by pollution

Emissions may breach the government's clean-air targets





Transport for London and Heathrow Airport


Real Science. Real Results.

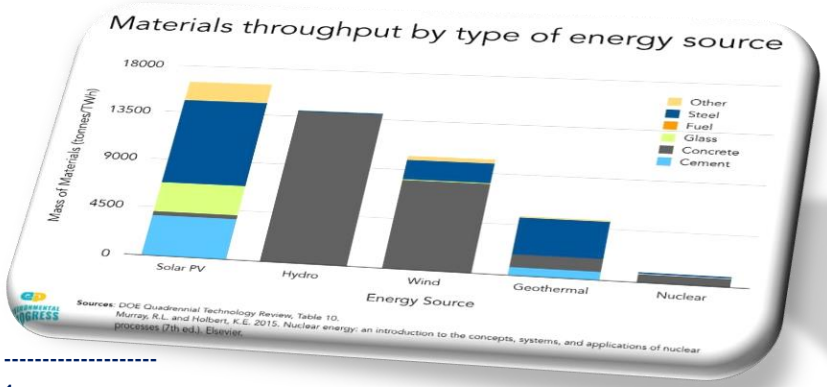

22
47.90
Ti
Titanium

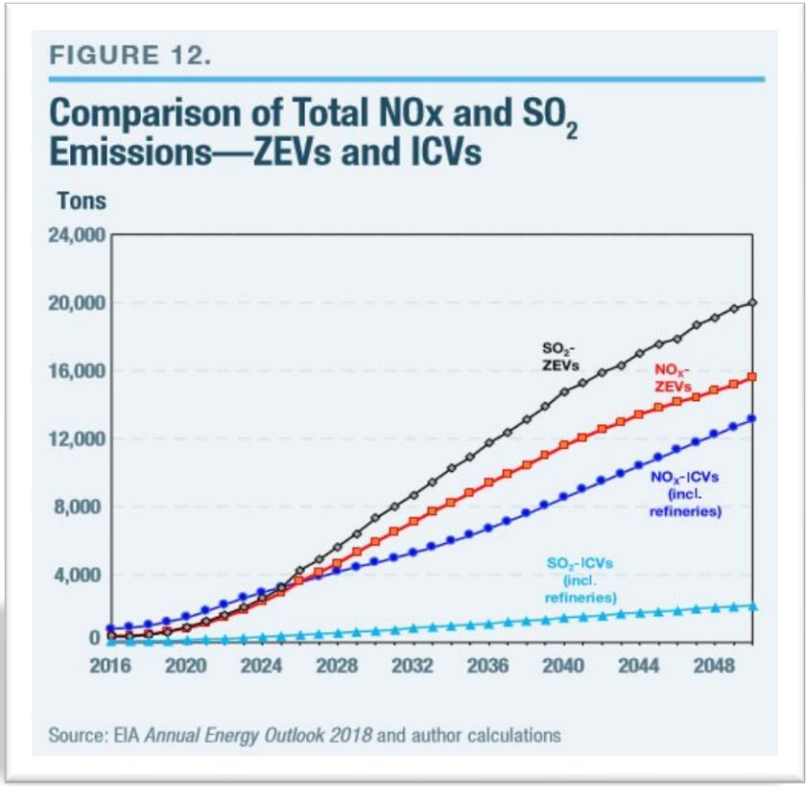
Current Solutions Failing

Electric Vehicle Conundrum

EV Drawbacks are Significant

- ✓ Forecast for RISING NO_x under EV [1]
- ✓ Electricity Production worse for Environment
- ✓ EVs Produce 50% More Greenhouse Gases [2]
- ✓ New Gasoline Engine Standards Lowering Emissions
- ✓ Renewables: Unreliable, Not Storable and High Cost [3]
- ✓ Cost to Overhaul US Energy Infrastructure >$10 Trillion [4]





---

[1] Lesser JA, *Short Circuit: The High Cost of Electric Vehicle Subsidies*, Manhattan Institute, May 2018.

[2] Tsinghua University, *Applied Energy* [Journal], May 2018.

[3] U.S. Department of Energy, *Quadrennial Technology Review* 2015.

[4] University of Texas (Austin) Energy Institute; Stanford University, School of Earth, Energy & Environmental Sciences.

U.S. Energy Information Administration; Manhattan Institute; PG&E; U.S. Department of Energy

It would take >7 billion Solar Panels to Support the Conversion of the US Auto Industry [1]

22 47.90 Ti Titanium

<1% Electric Cars would require 100% of Texas Electric Grid [2]

---

[1] Glenn H and Ost I, *pick-my-solar.com*, May 2018; Herron, David, *GreenTransportation.Info;* BlackwallPartners LLC estimates.

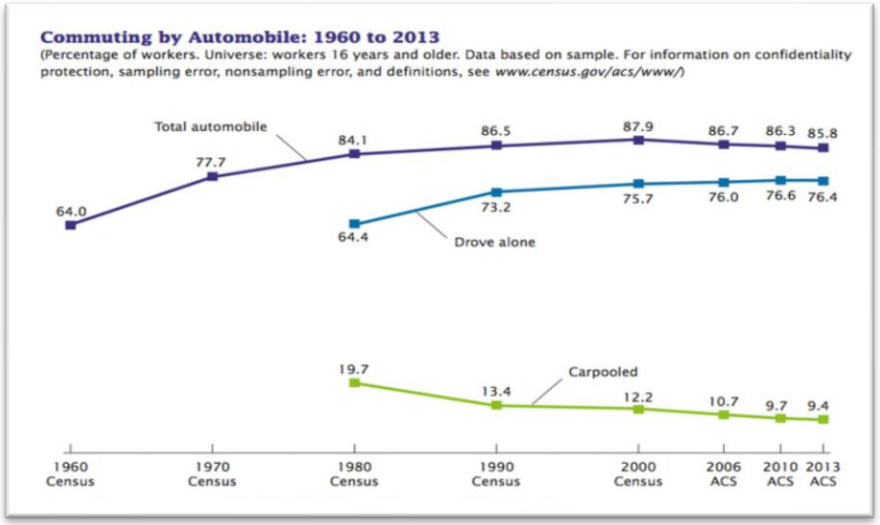
[2] RSC Backgrounder: *A Greedy New Steal*, The Republican Study Committee, February 2019, Mike Johnson, Chairman.

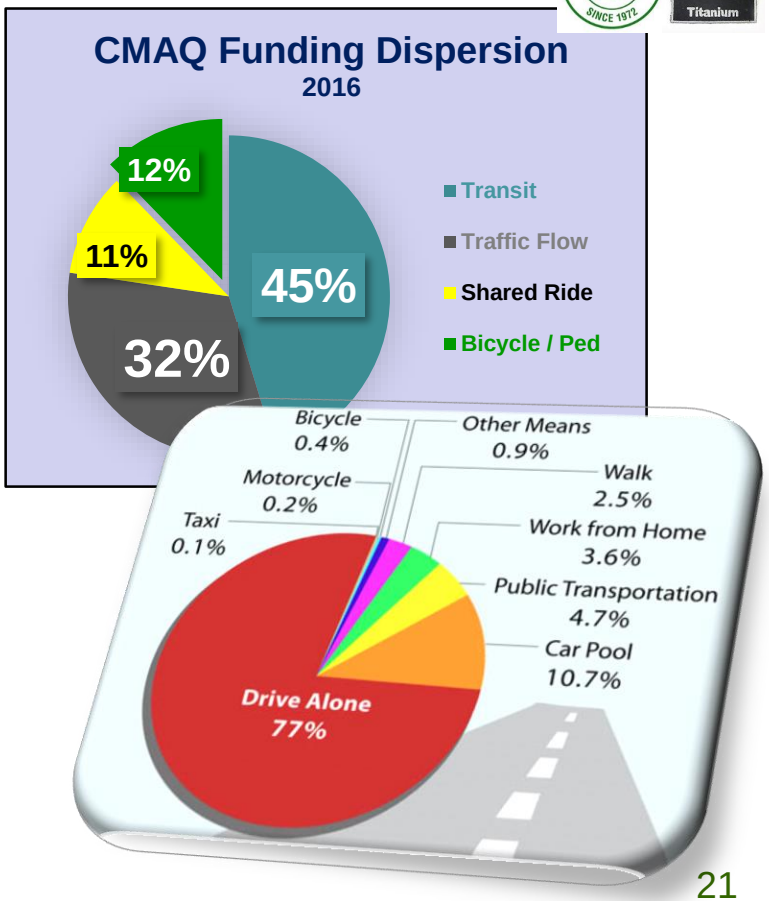
Commuter Pushback

132 Million Americans Commute to Work[1]

Commuter Preference vs. Funding Mismatch

- ✓ **Since 1980 Drivers INCREASING Independence**
- ✓ **50% of Funds Spent on <5% Public Transit Adoption**
- ✓ **Carpooling Dying Slow Death**





---

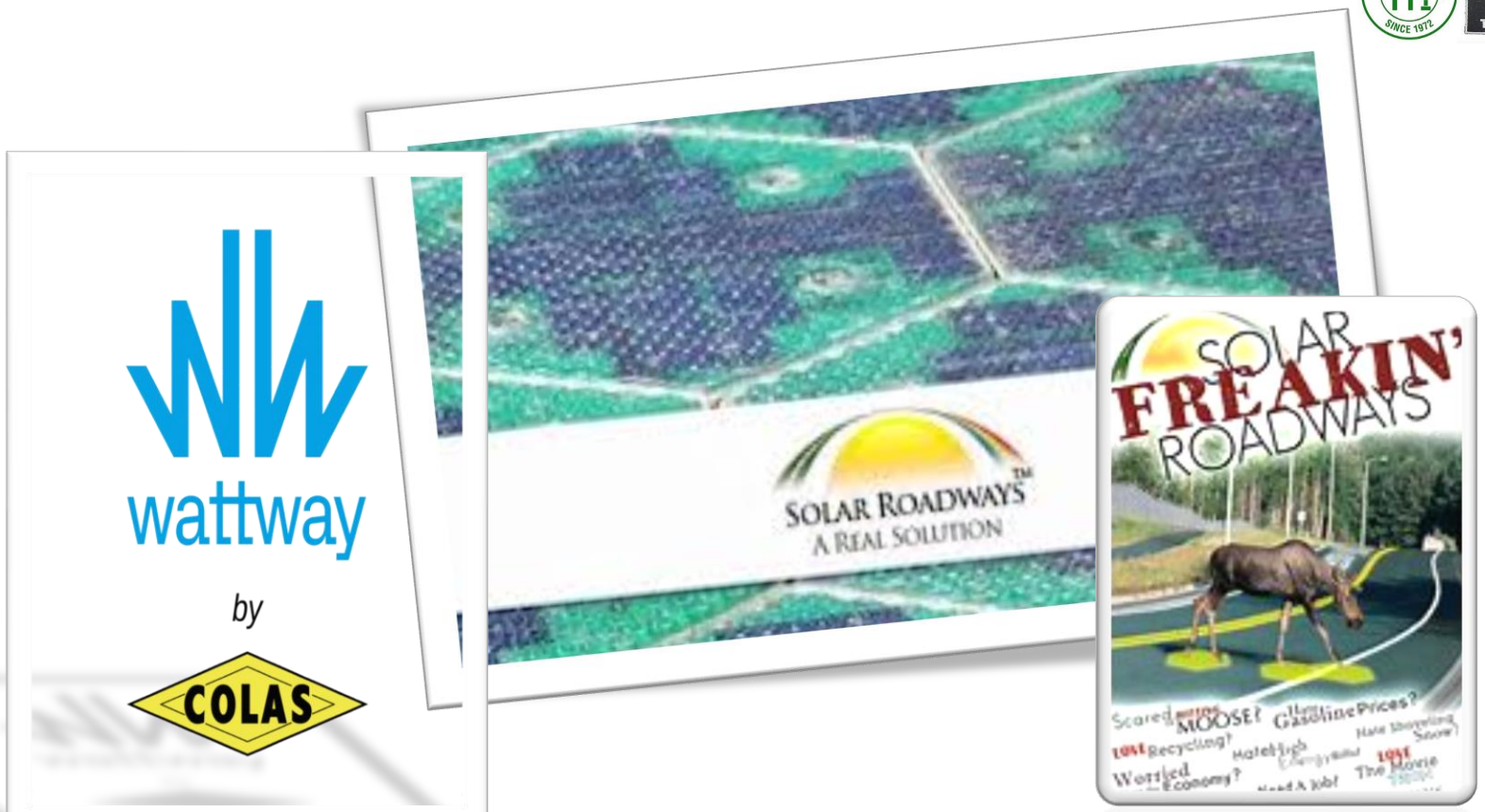
[1] U.S. Census Bureau, American Community Survey (ACS) 2017; Brookings Institute, *America's Commuting Choices: 5 Major Takeaways from the ACS*.

Federal Highway Administration; BlackwallPartners LLC estimates


HOV Lanes
Have Failed


22 47.90
Ti
Titanium
Ride Share? Well…

Photovoltaic Roads?



Our Sun Emits 3.86 x 10^{26} Watts of Energy (Hint: A lot)

Wait… The Sun is the Great Untapped Resource

"America needs an Energy Policy that's Big Enough to Matter; yet Politically Correct Enough for the General Public"

Kenneth A. Hersh, CEO George W. Bush Center

Green New Deal Price Tag >$90 Trillion

22 47.90
Ti
Titanium

"U.S. needs Greenhouse Gas 'Capture Technologies' to provide Grid Reliability and to Reduce Energy Costs"

Rob Jackson, Senior Fellow Stanford Earth

Solar Power: Catalytic vs. Voltaic

Photocatalysis: Direct "Capture Technology"

- ✓ **Natural Photocatalyst TiO_2 Absorbs Light Energy Becoming "Active"**
- ✓ **Electrochemical Energy Field Develops**
- ✓ **Adsorbed Pollutants Oxidized Traveling thru Field**
- ✓ **Capturing & Removing the Airborne Threat**
- ✓ **Powerful, Cheap and Sustainable at Source**

Photovoltaic: Indirect "Conversion Technology"

- ✓ **Manufactured Solar Cells installed to Absorb Light Energy**
- ✓ **Creates Electric Current**
- ✓ **Must be Transferred Immediately or Squandered**
- ✓ **Unreliable - Difficult and Prohibitively Expensive to Store**
- ✓ **Costly, Weak Energy only Pseudo-Sustainable**

22 47.90
Ti
Titanium

A Serious Solution

NO_x Capture

[Solar Energy-Based]

Photocatalysis w/ TiO_2

pho·to·ca·tal·y·sis
/ˌfōdōkəˈtaləsəs/
Noun CHEMISTRY
the acceleration of a chemical reaction by light

Photocatalysis is the **acceleration of a photo-reaction** by a semiconductor, where **Photo-Catalytic Activity (PCA)** is **naturally occurring** when the catalyst excites in the presence of radiant energy causing secondary molecular reactions. Its practical application was made possible by the discovery of water electrolysis by means of titanium dioxide or **TiO_2** in the seventies.[1]

Photocatalysis promises a solution to the challenges associated with the intermittent nature of sunlight which is considered as renewable and the **ultimate energy source** to power activities on **Earth**.

In the excited state, **TiO_2** triggers two simultaneous reactions - oxidation of near-field molecules from a photo-generated positive charge (electron holes) and reduction of oxygen via the escaping electrons in a process referred to as **Redox**, creating an electrochemical **energy field**.

Selective Catalytic Reduction (SCR) occurs as "Victim Molecules" such as **NOx** and **VOCs** travel through the energy field and are oxidized instantly (**Photo-Catalytic Oxidation**) while the catalyst **TiO_2** itself is not altered nor exhausted.

---

[1] **Honda-Fujishima effect: Fujishima A and Honda K, *Electrochemical Photolysis of Water at a Semiconductor Electrode*, Department of Applied Chemistry, School of Engineering, The University of Tokyo, 1972.**

Photocatalysis w/ TiO_2

Basic Quantum Mechanics drive Photo-Reactivity of TiO_2

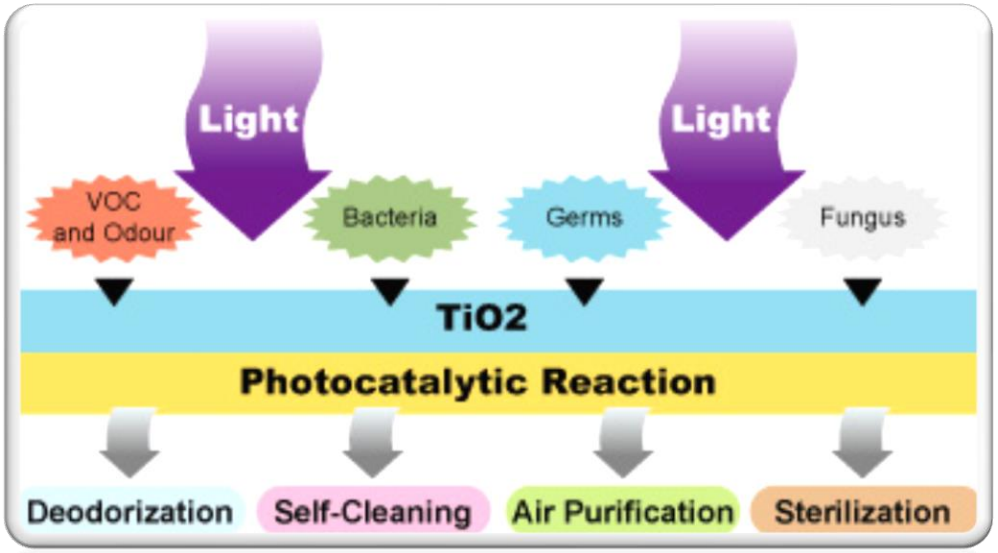
TiO_2 Properties / Advantages

- ✓ **Strong Oxidizer / De-polluting**
- ✓ **Light-Remitting / Heat-Reducing**
- ✓ **Water Adsorbing / Self-Cleaning**
- ✓ **Antibacterial / Anti-mold**

TiO_2 is…

- ✓ **Naturally Abundant**
- ✓ **Chemically Inert**
- ✓ **Non Exhaustive**

Natural Chemical Reaction



Remove Smog

Photocatalysis: Mother Nature's Pollution Fighter

Gas-Phase NO_x Photodegradation *via* TiO_2 [1]

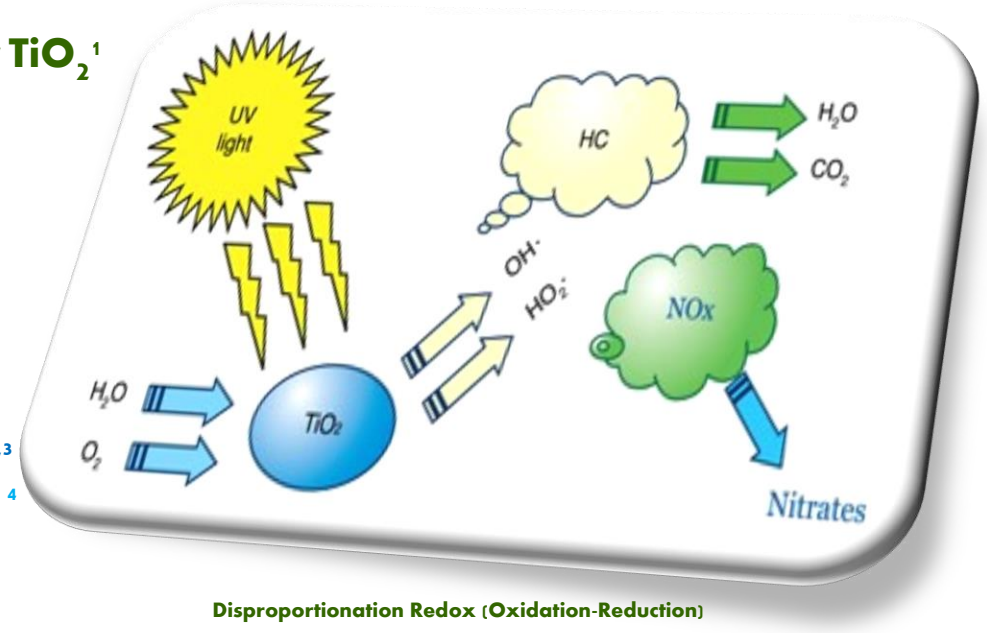
✓ Analogous to Plant Photosynthesis

Energy Field

- TiO_2 forms electron holes under UV light
- Creating a (photo) Excited State
- Whereby Radicals (OH-; $HO-_2$) and
- Superoxide ($O-_2$) decompose NO_x

✓ Results are Harmless Nitrate Salts
✓ Super Hydrophilic / Hydrophobic Surface [2,3]
✓ And a Beneficial Reflective (Cooling) Effect [4]

Photo-Catalytic Oxidation (PCO)



Disproportionation Redox (Oxidation-Reduction)

---

[1] Dalton, J.S. et al., Photocatalytic Oxidation of NOx Gases using TiO_2: A Surface Spectroscopic Approach, *Environmental Pollution*, 2002.
[2] Superhydrophilicity: Research Institute of Toto Ltd, Japan 1995.
[3] Arainpour F and Farzaneh M, On Hydrophobic and Icephobic Properties of TiO_2-Doped Silicon Rubber Coatings, Department of Applied Sciences, Universite du Quebec, *International Journal of Theoretical and Applied Nanotechnology*, 2012.
[4] Zhous A et al., *Enhanced Solar Reflectance of Thermal Coatings through Inorganic Additives*, City University of Hong Kong and Massachusetts Institute of Technology, Hong Kong / Boston 2016.

Cut Acid Rain

Significant Environmental and Ecological Net Benefits

Nitrite Gas Converted into Solid Nitrate is a 99.9% "Pollution Equivalent" Reduction [4]

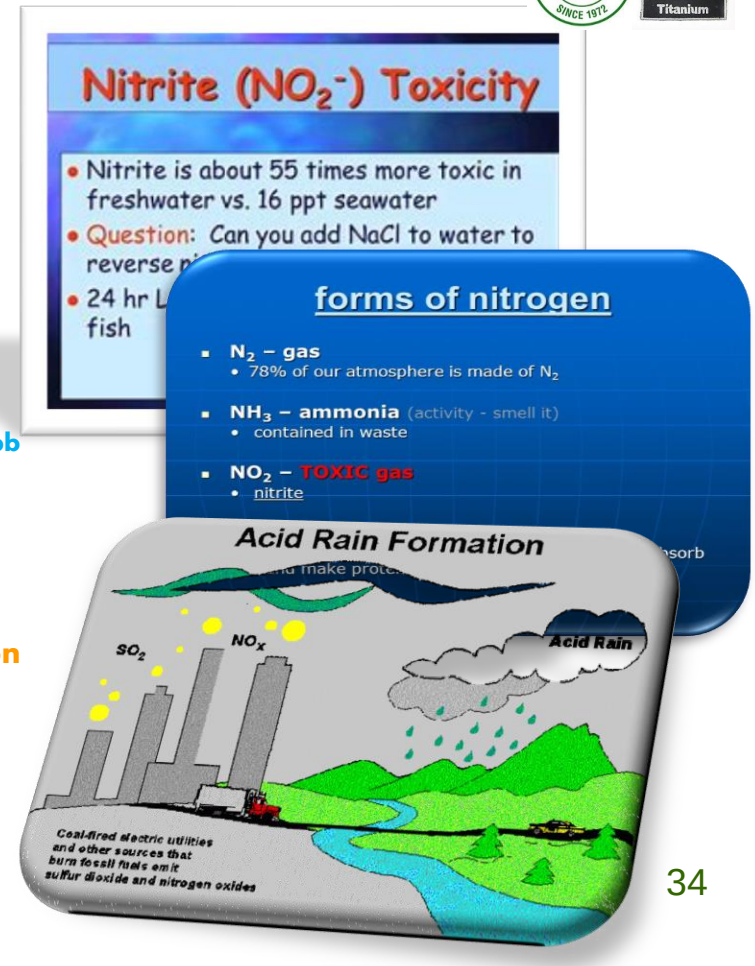
- ✓ **Airborne Nitrites (NO_2) are Highly Toxic**
- ✓ **Nitrates (NO_3) Least Harmful Form of Soluble Nitrogen**

Significant Positive Trade-off

- **EPA NO_2 Air Quality Maximum[1] 53 ppb or 0.05 mg/L**
- **EPA NO_3 Water Contamination Maximum[2,3] 45 mg/L or 45,000 ppb**
- **Airborne Nitrites 849x More Toxic than Desorbed Nitrate [4]**
- **Acid Rain 55x More Toxic to Freshwater [5]**

Smart Airshed and Watershed Management:

- ✓ **Acid Rain Averted; Benign Nitrates Absorbed by Vegetation**
- ✓ **NO_3 only 22.5% Nitrogen = Watershed Net Benefit [3]**



---

[1] Environmental Protection Agency National Ambient Air Quality Standard for maximum annual concentration for NO_2 (2010).
[2] Environmental Protection Agency NO_3 maximum contaminant level for water (2012);
[3] University of Georgia, College of Agriculture and Environmental Sciences.
[4] BlackwallPartners LLC estimates.
[5] Washington University (St. Louis), Department of Chemistry.

Reduce Heat Islands

Nano TiO_2 Treated Surfaces Promote High-Efficiency No Glare Solar Reflectivity (SR) [1,2,5]

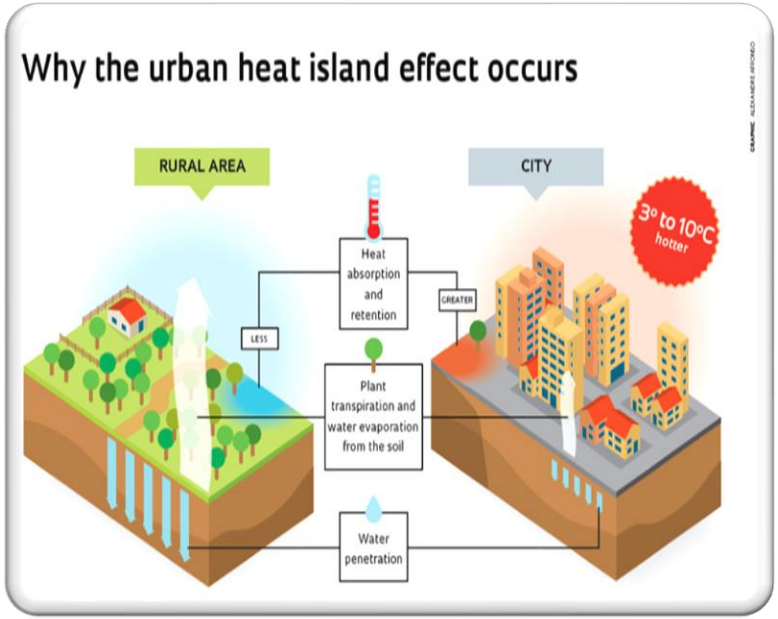
Be Cool

- ✓ **TiO_2 Scatters UV Light Energy by Diffraction**
- ✓ **Pavements Make-Up 1/3 of a City**

Asphalt Damage

- **Asphalt has Ultra Low SR Index (0.05 to 0.20)** [1]
- **An SRI of 0.05 @ 72F = 140 Degrees!** [1,3]
- **Asphalt Binder Photo-Degrades at 120 Degrees** [4]
- **Each 0.10 SRI Lowers Temp by 7-10 Degrees** [1,2,3]

- ✓ **Exponential Improvement as Air Temps Rise**
- ✓ **Longer Pavement Life Cycle (LCA)**
- ✓ **30% Lower Street Lamp Energy** [1,3]



---

[1] Environmental Protection Agency, Heat Island Reduction Program (presentation), Los Angeles, 2018.

[2] Zhous A et al., *Enhanced Solar Reflectance of Thermal Coatings through Inorganic Additives*, City University of Hong Kong; Massachusetts Institute of Technology, Hong Kong / Boston 2016.

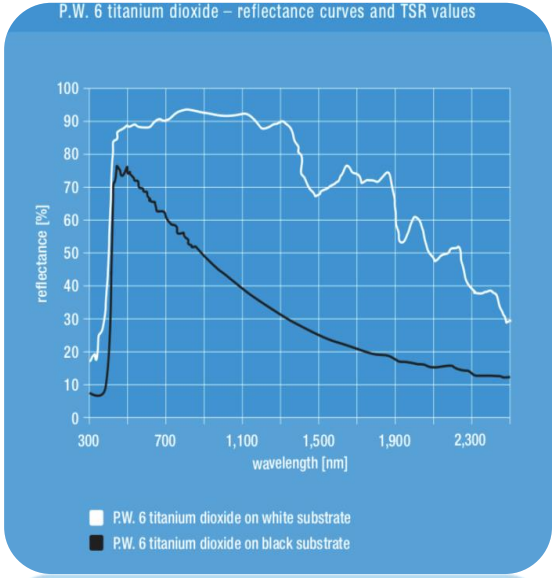
[3] Pomerantz H et al., Heat Island Group, Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, *Examples of Cooler Reflective Streets for Urban Heat-Island Mitigation*, Berkeley, California.

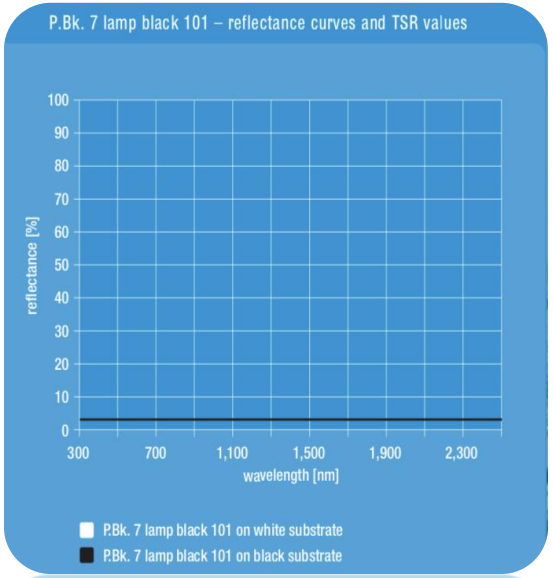
[4] Hossain K and Karakas AS, *Effect of Ultraviolet Aging on Rheological Properties of Asphalt Cement*, Memorial University of Newfoundland and University of Illinois, Urbana-Champaign, June 2018.

[5] Wiechers S et al., *Titanium Dioxide Particle vs. Sun Protection Performance*, Evonik Industries AG and Aqura GmbH, August 2013.

Reduce Heat Islands

Nano TiO_2 Treated Surfaces Promote High-Efficiency No Glare Solar Reflectivity (SR)

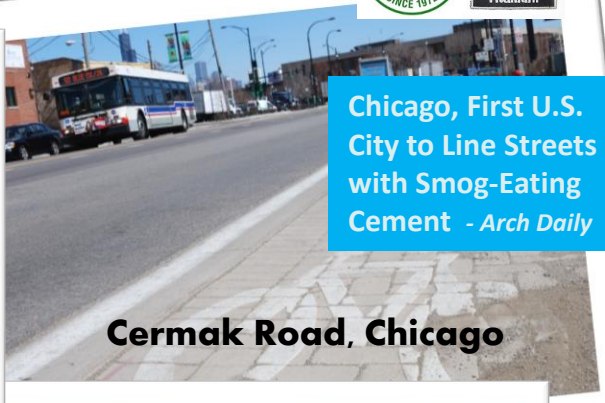




---

[1] **BASF SE "Cool Pigments for Cool Surfaces".**

TiO_2 in Design



Chicago, First U.S. City to Line Streets with Smog-Eating Cement - *Arch Daily*

TECHNOLOGY

A Building That Eats Smog

Take that, air pollution

By Nicole Lou February 9, 2016

Smog-Eating Pavement In Netherlands Can Cut Pollution By Up To 45 Percent, Study Says - ***Environment Magazine*** 07/09/2013

TiO_2 in Design

- ✓ **Rapid Water Releasing**
- ✓ **Pollutant Neutralizing**

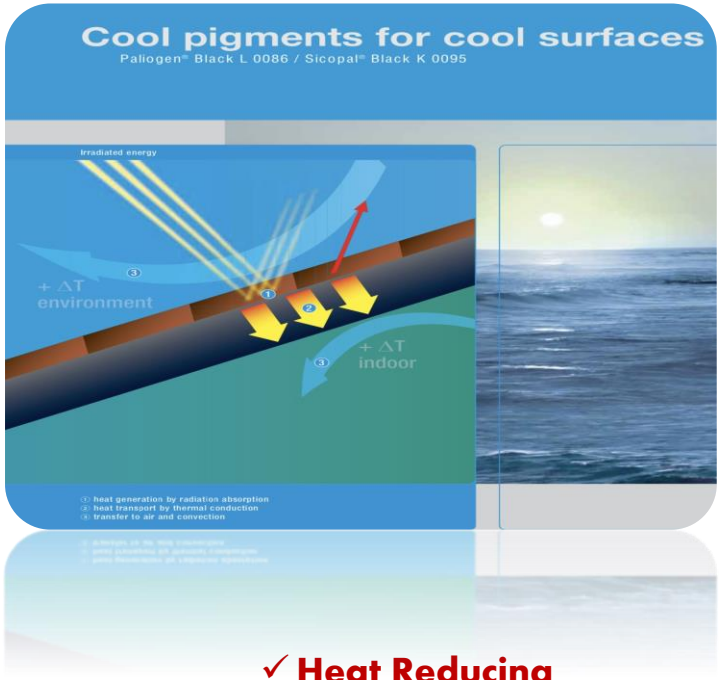
Toto Neorest NX2 Toilet w/ ACTILIGHT Technology, Toto Ltd Japan

TiO_2 in Design

✓ Air Purifying
✓ Self-Cleaning

Alcoa Architectural Coatings – EcoClean Aluminum Panels, Alcoa Corporation

TiO_2 in Design

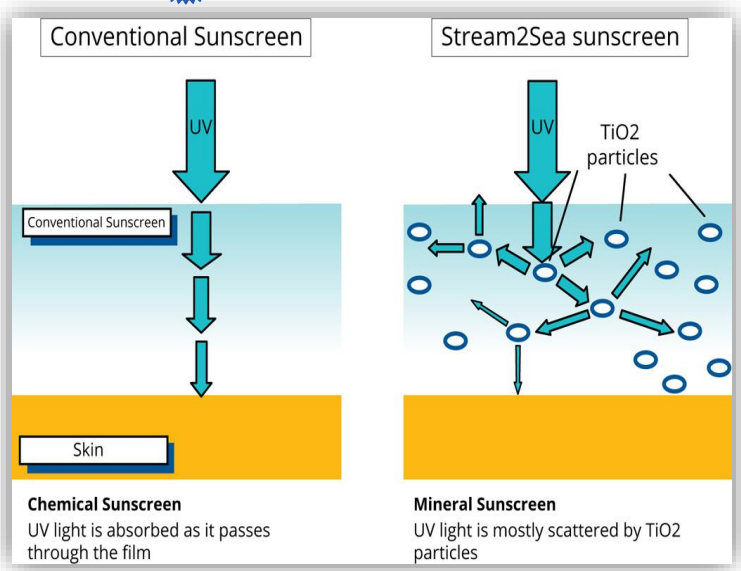


✓ **Heat Reducing**
✓ **More Sustainable**

TiO_2 in Design

- ✓ **Super Reflective**
- ✓ **Energy Displacing**

STREAM2SEA

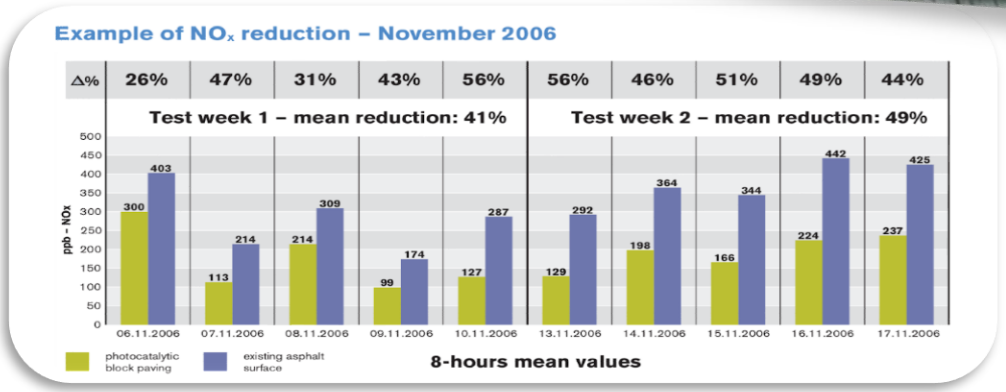


Johnson & Johnson Consumer Inc.; La Roche-Posay; Stream2Sea

TiO_2 in Design

Bergamo, Italy

- ✓ Near-Field (Road-Level) Ozone Removal Trial
- ✓ New Construction TiO_2 Photocatalytic Concrete
- ✓ In-Situ Two Week 8 Hour NO_x Reduction Test
- ✓ Mean Efficiency 41% to 49%



Intalcementi S.P.A.: HEIDELBERG Cement Group

---

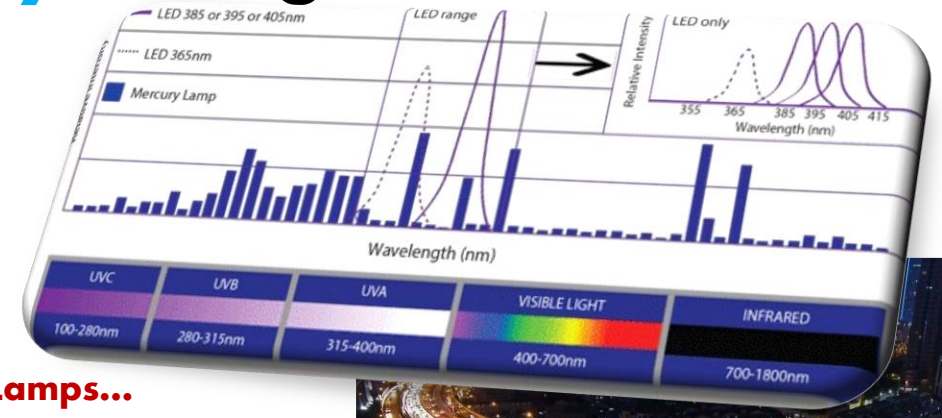
[1] Alcoa Architectural Coatings – EcoClean Aluminum Panels; Nowak D, U.S. Forest Service: *Air Pollution Removal Capacity of Urban Forests*;

Offsetting the Emissions of up to 4,000 Cars Daily or 19,000 $CO_{2(e)}$ Metric Tons of Pollution[1]

---

[1] Dios J et al., *Decontamination through Photocatalytic TiO_2 Additions – Past, Present and Future,* International Conference on Emerging Trends in Engineering and Technology (ICETET), London 2014; BlackwallPartners LLC estimates per center lane mile on a 'high volume' roadway (AADT).

Photocatalytic Roads can work Day and Night



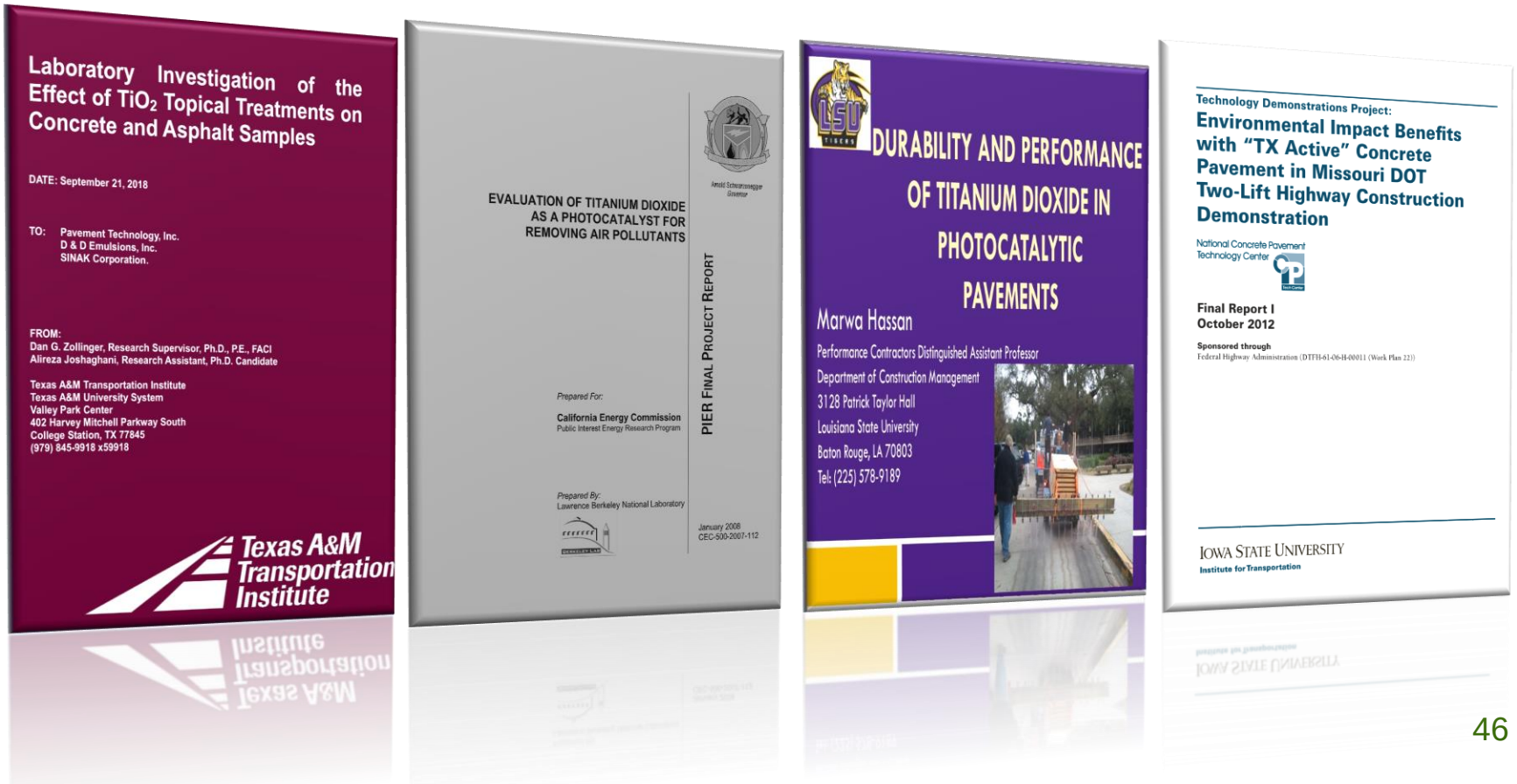
TiO_2 Triggered by Radiant Energy

- ✓ From Auto Headlamps to Street Lamps…
- ✓ Newest Auto Lamps are LED UVA
- ✓ Technology Moving towards Optimal Safety [1]
- ✓ Falling Right into Efficient Photocatalytic Range
- ✓ Visible-Light Responsive (Doped) TiO_2 Photoactivity [2,3]

---

[1] Federal Highway Administration, *A Safety Evaluation of UVA Vehicle Headlights* (2010).
[2] Pei D and Luan J, Development of Visible Light-Responsive Sensitized Photocatalysis, *International Journal of Photoenergy*, August, 2011.
[3] Dette C et al., *TiO_2 Anatase with a Bandgap in the Visible Region*, University of Oxford, 2014.

The Literature



22 47.90
Ti
Titanium

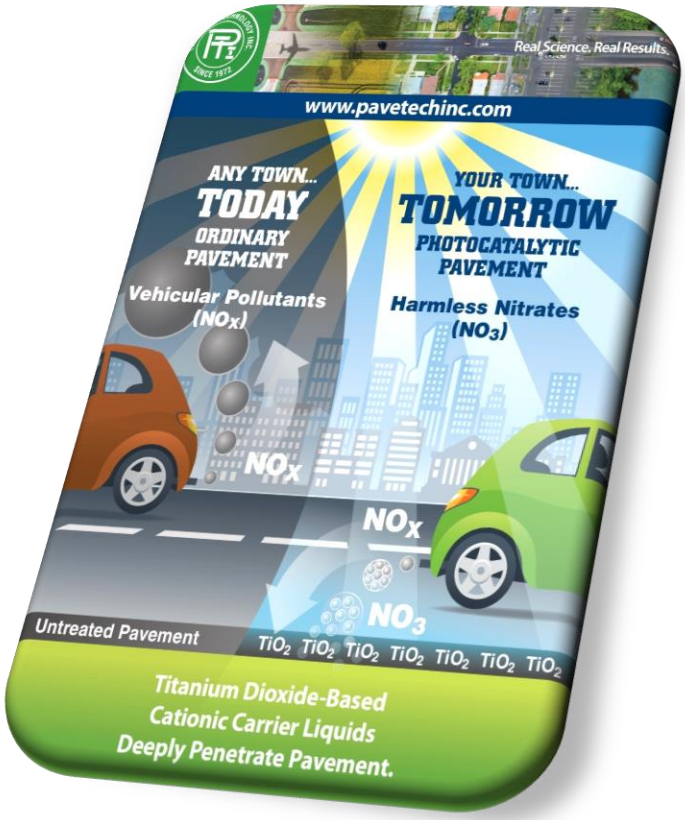
Now... the Technology to Deliver It

TiO_2 Product Set

What is Pavement Technology plus TiO_2

*A technological breakthrough combining proven surface penetrating pavement preservation compounds with a known catalytic system designed to significantly reduce pollution levels at combined (**cost-effective**) application economics. Key is the patented, penetrating properties which stabilize **TiO_2** deep into the roadway, creating a sustained photocatalytic (**smog-eating**) and heat reducing pavement.*

*The pollution-reducing pavements react with light to break down primary ozone pollutants such as **NO_x** and **$VOCs$** – effectively cleaning the air at its inceptive and most vulnerable point of contact, the very road surface, providing a calculable environmental benefit… all while helping sustain pavement performance and longevity.*



United States Patent and Trademark Office: US 8,899,871 B2; US 9,493,378 B2

TiO_2 Product Set

22 47.90
Ti
Titanium

Pavement Technology, Inc. 800-333-6309

A.R.A.-1 Ti® pollution-reducing polymerized rejuvenating seal

Formulated from the same maltene fractions that vitalize asphalt binders, A.R.A.-1 Ti® rejuvenating seal revitalizes aging asphalt while leaving behind a self-cleaning surface that removes nitrogen oxides (NOx), volatile organic compounds and other pollutants introduced into the atmosphere through vehicular exhaust. The air-purifying surface perpetually regenerates itself throughout the life of the pavement, contributing to compliance with U.S. EPA's stringent new National Ambient Air Quality Standard (NAAQS). The ideal solution for government agencies dealing with reduced budgets, deteriorating infrastructures and pollution concerns.

Markets
- DOTs
- Urban/Suburban Municipalities, Counties, Gated Communities
- Airports
- Bridges
- Parking Lots
- Highway Shoulders

Compatible Substrates
- For newly constructed asphalt pavement, A.R.A.-1 Ti rejuvenating seal improves durability by replacing volatile components lost to the heat of production, providing an in-depth seal to reduce permeability.
- For older asphalt pavement, A.R.A.-1 Ti rejuvenating seal reverses the effects of UV, weathering and water intrusion by reintroducing volatile components deep into the asphalt to restore ductility and flexibility.

Benefits
- Penetrates deeply to protect against air and water – not a topical coating
- Provides a self-cleaning, self-regenerating, air-purifying surface that removes nitrogen oxides (NOx) volatile organic compounds (VOCs) and other airborne pollutants from the atmosphere for the life of the structure
- Prevents stripping and raveling of the aggregate
- Reduces long-term pavement maintenance costs by extending the life of new and existing asphalt pavements:
  - Increases the durability of the top portion of new asphalt pavements
  - Improves the ductility and flexibility of the top portion of aging asphalt pavements
- Will not obliterate striping and other markings
- Supports NAAQS compliance

How It Works
The A.R.A.-1 Ti maltene-based emulsion restores the reactive components that asphalt pavements lose due to hot-plant operations and the aging process. The emulsion delivers photocatalytic TiO_2 deep into the asphalt surface, leaving behind a photocatalytic surface layer that removes NO_x, volatile organic compounds (VOCs) and other airborne pollutants from the atmosphere for the life of the pavement. As weather and traffic wear the surface layers of pavements, deeper layers of TiO_2 are exposed at the surface in a self-generating process of air purification.

How to Apply
Temperature
Apply only when ambient temperature is expected to remain at or above 40°F during application and for the next 12 hours.

Surface Preparation
Surface must be dry with no threat of rain within 4 hours of application.
Field testing shall be performed prior to application to determine the maximum amount of material that the pavement can absorb within a 20 minute period. Contractor shall apply various test strips ranging in length from 100-150 ft. using different rates, noting the time it takes for total absorption to occur without surface residues remaining.

Pavement Technology, Inc. 800-333-6309

Litho1000Ti® pollution-reducing concrete sealer/hardener

Litho1000Ti® pollution-remediating concrete sealer/hardener waterproofs and restores aging and newer concrete, sealing it against chloride ion penetration, deicing salts, sea-water environments and freeze/thaw cycling, while improving its durability and reducing vehicular exhaust pollutants. Its air-purifying surface perpetually regenerates itself throughout the life of the concrete, resisting weathering, stain and traffic-related wear while contributing to compliance with U.S. EPA's stringent new National Ambient Air Quality Standard (NAAQS). Technical assistance is available from the manufacturer and its trained field representatives.

Markets
- Bridges
- DOTs
- Urban/Suburban Municipalities and Counties
- Airports

Compatible Substrates
Concrete surfaces of any age, including:
- Pavements
- Bridge Decks
- Parapet Walls
- PCC Paving
- Parking Decks
- Pre-Cast Concrete
- Vertical Cast-in-Place Concrete

Benefits
- Seals and waterproofs concrete surfaces, significantly reducing the concrete's permeability and sorptivity
- Improves the hardness of the concrete aggregate and paste matrix
- Provides a self-cleaning, self-regenerating, air-purifying surface that removes nitrogen oxides (NO_x), volatile organic compounds (VOCs) and other airborne pollutants from the atmosphere for the life of the structure
- Increases the surface durability of pavements and bridge decks
- Contributes to the higher abrasive value of exposed aggregate
- Will not impede the bonding properties of joint sealants, patching materials, lane markers or paint striping
- Will not stain, discolor or darken concrete, alter or coat its surface texture or alter its skid number (SN) rating
- Compatible with traffic paint, striping, cementitious toppings, joint sealants, crack repair processes and typically applied paint and coating systems

How It Works
Litho1000Ti® concrete sealer/hardener is a water-based lithium silicate with titanium dioxide added in a proprietary formula in solution to remediate airborne pollutants. It requires no mixing or diluting and contains no VOCs or solvents.

The proprietary Litho1000Ti® formulation chemically alters the absorptive aggregate of concrete to increase its durability. Unlike topical sealers that merely coat the top surface of the concrete, the lithium silicate in Litho1000Ti® sealer/hardener reacts with the hydrating cement to produce additional gel products near the concrete surface. These added gel products create an in-depth seal by filling the concrete capillaries that would otherwise allow water to penetrate through the concrete surface.

As an added benefit, the gel delivers photocatalytic titanium dioxide (TiO_2) deep into the concrete structure. The resulting air-purifying surface reduces pollutants related to vehicular exhaust. As surface layers deteriorate through exposure to weather and traffic, submerged layers of TiO_2 are newly exposed, perpetuating the air purification process.

How to Apply
Temperature
Apply only when ambient temperature is above freezing. Product that has frozen will not function properly and must be discarded.

Real Science. Real Results.

Pavement Technology, Inc. 800-333-6309 www.pavetechinc.com

Ti-introCME™ pollution-reducing penetrant

Ti-introCME™ cationic molecular emulsion penetrant is a titanium dioxide (TiO_2) suspension in a carrier liquid that penetrates asphalt and concrete pavement to a depth of 1/8 to 1/4 inch, delivering TiO_2 to the surface and upper matrix of the structure. The penetrant provides the catalyst for a photocatalytic reaction that reduces atmospheric vehicle exhaust gas, removing nitrogen oxides (NO_x), volatile organic compounds (VOCs), and other pollutants generated by automotive and truck traffic. The liquid carrier is a cationic aqueous emulsion with a proven track record for effectively transporting various chemicals into a pavement matrix.

Ti-introCME penetrant uniformly distributes TiO_2 throughout the area in a process known as distributive embedding. Pavements treated with Ti-introCME penetrant inhibit the degradation of air quality surrounding America's roadways.

The Vehicular Pollution Challenge
Detrimental gas emissions, such as nitrogen oxides (NO_x) and sulfur oxides (SO_x), are formed during the vehicle combustion process. Diesel vehicle emissions introduce one of those oxides (nitrogen dioxide (NO_2)) into the environment, increasing ozone concentrations. As the ozone concentrates, the percentage of nitrogen oxides undergoing oxidization also increases, resulting in an increasingly higher percentage of NO_2 in the atmosphere.

Research has identified a clear association between serious environmental issues, such as photochemical smog and acid rain, and NO_x. The ratio of NO_2 to NO_x has been increasing over the years due to increasing traffic and a corresponding increase in ozone concentrations. U.S. Environmental Protection Agency (EPA) technical data shows more than 50 percent of atmospheric NO_x is emitted from mobile sources.

A.R.A-1 Ti Application

Several approaches, including photo catalysis, have been studied as methods for counter-acting NO_x emissions. Photo catalysis is the acceleration of a photo-reaction (light absorbing) in the presence of a catalyst. A semiconductor activated by Ultraviolet (UV) light with wavelengths less than 380 nm creates hydroxyl radicals and superoxides. This irradiation can naturally decompose the organic pollutants, such as NO_x.

TiO_2 has been used as a photo catalyst for several reasons. First, TiO_2 fulfills the requirements for effective photo activity under solar radiation. Secondly, TiO_2 has a solid oxidizing strength at ambient conditions. The band gap of the solid state enables TiO_2 to be beneficial in the UV section of the spectrum. Finally, TiO_2 is chemically inert, physically stable, non-toxic and super hydrophilic.

Markets
- DOTs
- Urban/Suburban Municipalities, Counties, Gated Communities
- Airports
- Bridges
- Parking Lots
- Highway Shoulders

Compatible Substrates
- For newly constructed asphalt pavements where traffic is restricted on closed construction sites, Ti-introCME provides cost-effective air pollution remediation on clean, receptive surfaces.
- For existing pavements, Ti-introCME provides retrofitted air pollution remediation without the need for expensive resurfacing or reconstruction.

1) Pollution Remediate +
2) Preservation Agent

Asphalt
✓ **Maltene Replacement**

Concrete
✓ **Lithium-Quartz Densifier**

3) or

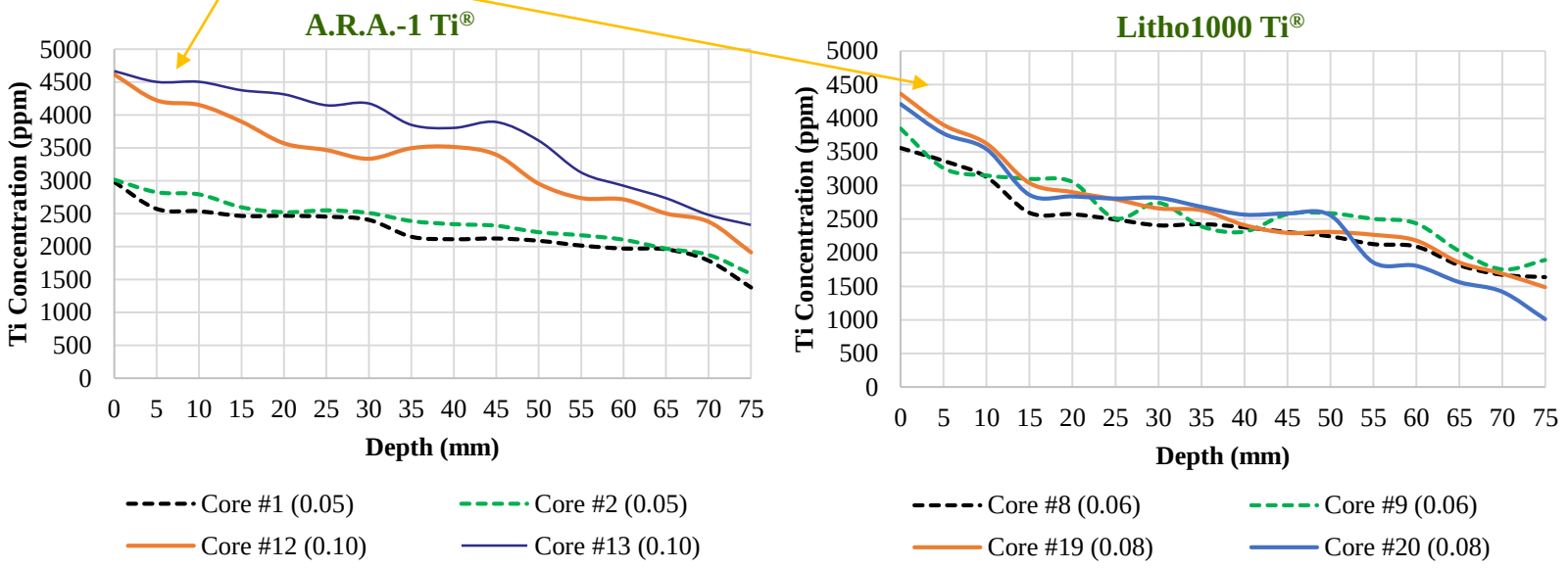
Any Surface
✓ **TiO_2 Only**

Asphalt **Concrete** **All Infrastructure**

Testing[1] - Deep TiO_2 Penetration

Orlando International Airport

High Concentration Wearing Course Depth

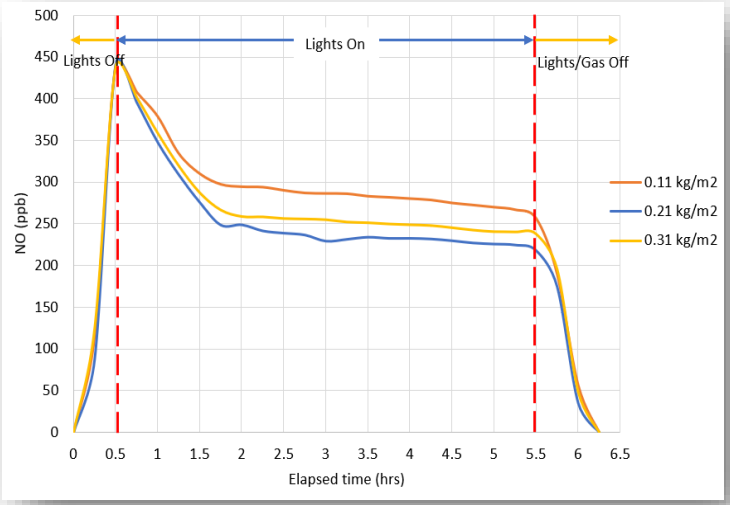


Texas A&M Transportation Institute

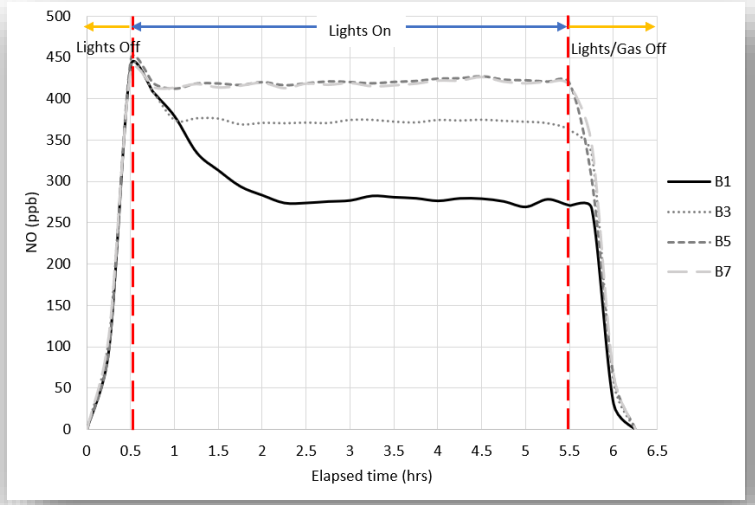
[1]Zollinger DG. and Joshaghani A, *Laboratory Investigation of the Effect of TiO_2 Topical Treatments on Concrete and Asphalt Samples* (Follow-Up), Texas A&M Transportation Institute, June 2019.

Testing[1] - Consistent NO_x Removal

A.R.A.-1 Ti®



Litho 1000 Ti®



[1]Zollinger DG and Joshaghani A, *Laboratory Investigation of the Effect of TiO_2 Topical Treatments on Concrete and Asphalt Samples*, Texas A&M Transportation Institute, September 2018.

Testing[1] - Strong NO_x Reduction

Compound	NO Reduction Efficiency (%)					
Application Rate	Control Sample	0.05 gsy	0.06 gsy	0.08 gsy	0.10 gsy	0.12 gsy
A.R.A.-1 Ti®	NEGL	53%	57%	61%	53%	48%
Ti-introCME™	NEGL	48%	52%	55%	58%	53%

Application Rate		0.04 gsy	0.06 gsy	0.10 gsy
Litho 1000 Ti®	NEGL	46%	55%	48%

Texas A&M Transportation Institute

[1]Zollinger DG and Joshaghani A, *Laboratory Investigation of the Effect of TiO_2 Topical Treatments on Concrete and Asphalt Samples*, Texas A&M Transportation Institute, September 2018.

Testing[1] - Sustained Performance

A.R.A.-1 Ti®

Site	NO Reduction Efficiency (%)				
	Control Sample	Y1 Sample A	Y2 Sample A	Y1 Sample B	Y2 Sample B
Orlando (FL)	NEGL	28%	33%	34%	30%
Greenville (SC)	NEGL	38%	35%	43%	38%

Multi-Year In Situ Sustainability Tests

Texas A&M Transportation Institute

[1]Zollinger DG and Joshaghani A, *Laboratory Investigation of the Effect of TiO_2 Topical Treatments on Concrete and Asphalt Samples* (Follow-Up), Texas A&M Transportation Institute, June 2019.

Testing[1] - Advanced Field Success

Site	NO Reduction Efficiency (%)				
	Control Sample	A.R.A.-1 Ti® Sample A	A.R.A.-1 Ti® Sample B	Litho1000Ti® Sample A	Litho1000Ti® Sample B
Orlando International	NEGL	45%	43%	53%	57%
Charlotte Co.	NEGL			42%	46%

		TI-IntroCME™ Concrete Sample A	TI-IntroCME™ Concrete Sample B	TI-IntroCME™ Asphalt Sample A	TI-IntroCME™ Asphalt Sample B
Charlotte Co.	NEGL	48%	47%	49%	50%

[1]Zollinger DG and Joshaghani A, *Laboratory Investigation of the Effect of TiO_2 Topical Treatments on Concrete and Asphalt Samples* (Follow-Up), Texas A&M Transportation Institute, June 2019.

Testing[1] - Strong Heat Island Reduction

Compound / Substrate	Solar Reflectance Index Values					
Application Rate (a)	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
Application Rate (b)	Control Sample	0.03 gsy	0.06 gsy			
Ti-introCME™ / Asphalt	11	30	34			
Ti-introCME™ / Concrete	20	37	42			
Litho1000 Ti® / Concrete	25	41	46			

U.S. Green Building Council (USGBC) "Cool Pavement" = 29

American Public Works Assoc. (APWA) ISI Envision = 29

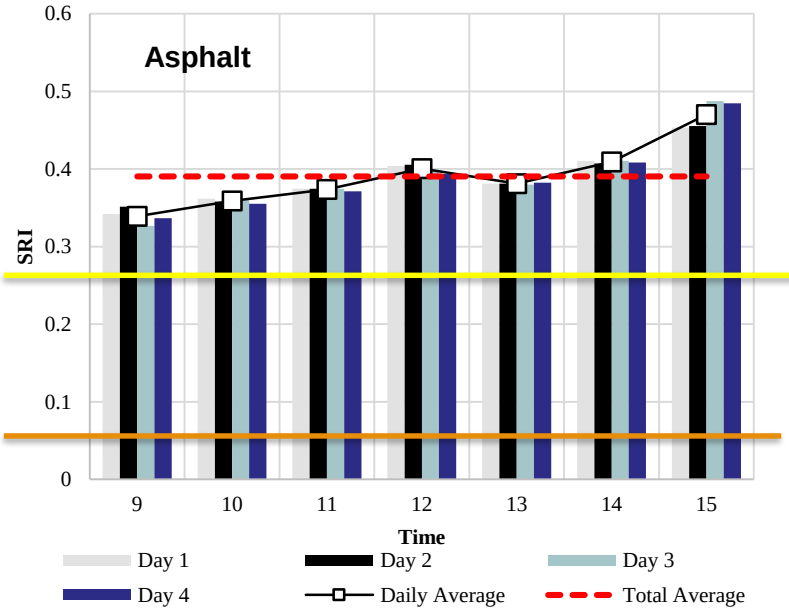
(a) Orlando International Airport; (b) Charlotte County (FL)

Texas A&M Transportation Institute

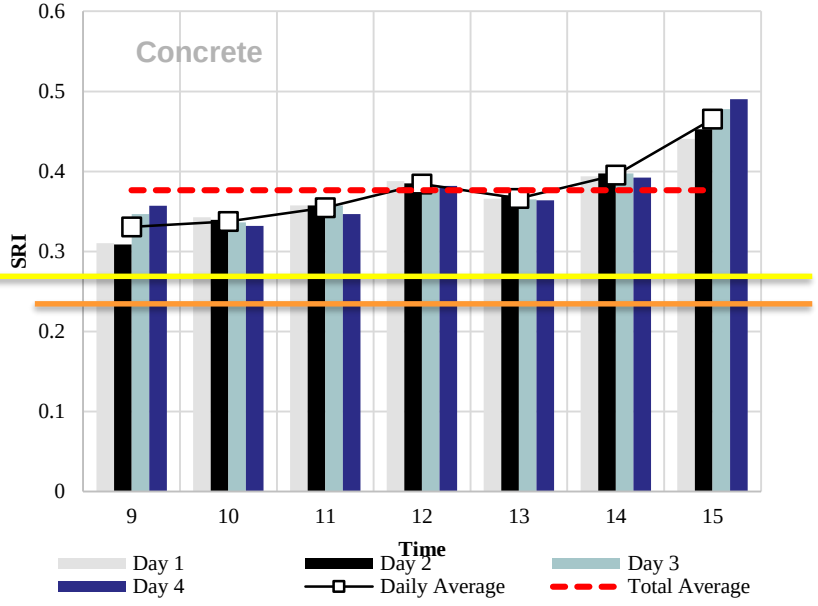
[1]Zollinger DG and Joshaghani A, *Solar Reflectance Analysis of TiO_2 Penetrant Treatments on Concrete and Asphalt Samples*, Texas A&M Transportation Institute, August 2019.

Testing[1] - Strong Heat Island Reduction

A.R.A.-1 Ti®



Litho 1000 Ti®



U.S. Green Building Council / American Public Works Assoc.

Untreated Solar Reflectance Index (SRI)

Texas A&M Transportation Institute

[1]Zollinger DG and Joshaghani A, *Solar Reflectance Analysis of TiO_2 Penetrant Treatments on Concrete and Asphalt Samples*, Texas A&M Transportation Institute, August 2019.

22 47.90
Ti
Titanium

The Road of the Future is Ready...

Smog Eating Roads

TiO_2-Bearing Pavements

- ✓ **Highly Competitive Clean Energy Source**
- ✓ **Requires No Change in Consumer Behavior**
- ✓ **Nor Overhaul of Power Systems**
- ✓ **Or Transportation Infrastructure**

TiO_2-Bearing Pavements

Implications

- ✓ Invisibly Reactive "Smog-Eating" Roadway Surface
- ✓ Confront NAAQS for Anthropogenic Pollutants at Point Source
- ✓ Reduce Urban Heat Island Effect (HIR)
- ✓ Cool Pavement promotes Pavement Life-Cycle Extension (LCA)
- ✓ Rain Desorbing / Ice Deterring
- ✓ Self-Cleaning lessens Fouling and Discoloring

Applications

- ✓ Roads; Bridges; Tunnels; Runways; Noise / Crash Barriers;
- ✓ Parking Garages / Ramps / Lots; Sidewalks / Walkways etc.
- ✓ Can be Combined w/ Pavement Preservation Treatments

22 47.90
Ti
Titanium

Retrofit Technology =
Cost Game Changer

Construction Costs

(square yard)

Photovoltaic Pavement	>$4,000
New Construction – TiO_2 Concrete	≥$200
New Construction – TiO_2 Asphalt	≥$100
TiO_2 Retrofit	<$5

BlackwallPartners LLC estimates

Construction Costs

(per)

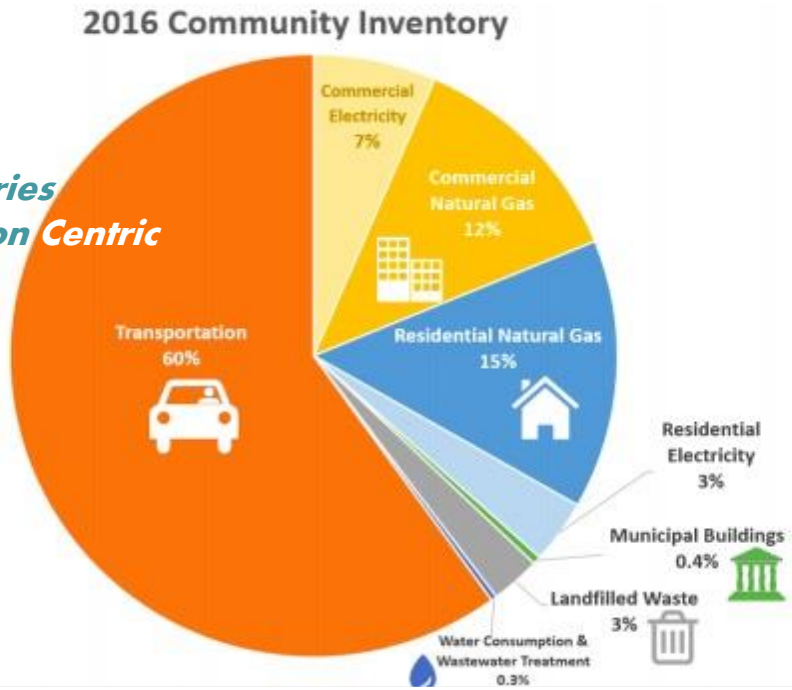
Because We Know You're Curious...

Photocatalytic Toilet	**$14,000**

Toto Ltd, Japan

Smart Cities and Photocatalytic Pavements

Greenhouse Gas Inventories are Heavily Transportation Centric



Environmental Protection Agency; City of St. Petersburg (FL)

Smart Cities and Photocatalytic Pavements

Pavement Technology Solutions Deliver...

- ✓ Longer Life-Cycle Pavements both rheologically and photo-chemically that Revitalize Performance and Boost Durability
- ✓ Bring-Down Replacement Costs
- ✓ Save Energy and Feedstocks which lessen Carbon Footprints
- ✓ Reduce and Reverse Heat Island Effects
- ✓ Provide a Practicable Solution for Removing Greenhouse Gases to Clean Our Air
- ✓ Promoting Vast Health and Economic Benefits

Sustainability Resilience Environment Economy

Real Science. Real Results.

www.SmogEatingRoads.com