WRI^2 = WRI'S WASTE RE-ENGINEERING INITIATIVE

JEAN-PASCAL PLANCHE, PHD, JERAMIE ADAMS, PHD,

YOGESH KUMBARGERI, PHD, JOE ROVANI, LEANNE HAZARD

Western Research INSTITUTE

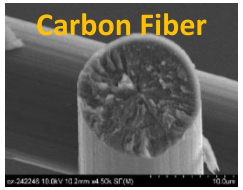
Outline

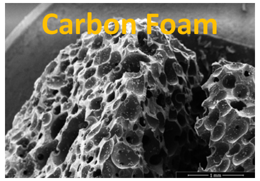
- WRI overview
- Context – background
- Why WRI^2?
- Examples
- Summary
- Perspectives

Western Research INSTITUTE

WRI overview

- Non-profit 501-C3 (since 1983)
  - Laramie, Wyoming, USA
- Expertise in Emerging Technologies
  - Petroleum & Coal products / processes
    - Bitumen partial upgrading / Deasphalting
    - Complete and versatile toolkit
      - Lab to pilot scale
      - Analytical & testing
      - Proprietary processes and methods
  - Hydrocarbons beyond combustion
    - Binders and carbon materials
  - Circular economy – Wastes Re-Engineering Initiative (WRI)
    - Plastics, aged asphalts processing & recycling





- Petersen Asphalt Research Conference
  - 59th PARC: July 19-21, 2022
  - “Asphalt Chem. Relations to Properties” training
  - www.petersenasphaltconference.org

Expertise

Asphalt and Hydrocarbon Materials, Heavy Oils, Coals, Biomass, Plastic Wastes, Emerging Methods and Processes

❖ **Chemistry**
- Formulation
- Synthesis
- Reaction/Oxidation
- Blending
- Conditioning
- Recycling

❖ Physical Chemistry
- Microstructure
- Compatibility

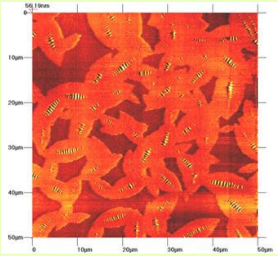
❖ Analytical Chemistry
- Composition
- Method development

❖ Chemometrics
- Machine learning
- Modeling

❖ **Material Physics**
- Mechanics, rheology & failure
- Thermal analysis

❖ Design & Evaluation
- Compaction
- Moisture / Rutting
- Thermal cracking

❖ Field Survey
- Sampling
- Extraction
- Evaluation



❖ **Chemical Engineering**
- Fouling, coking, emulsions
- Separation, adsorption
- Distillation
- Pyrolysis, airblowing
- Extraction

❖ Carbon fiber mesophase

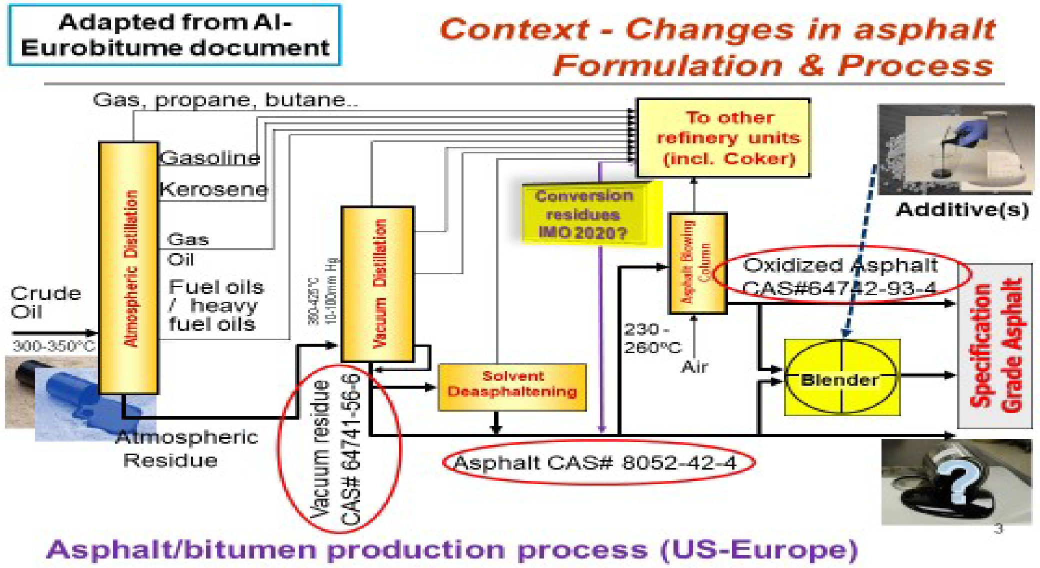
❖ Environment monitoring

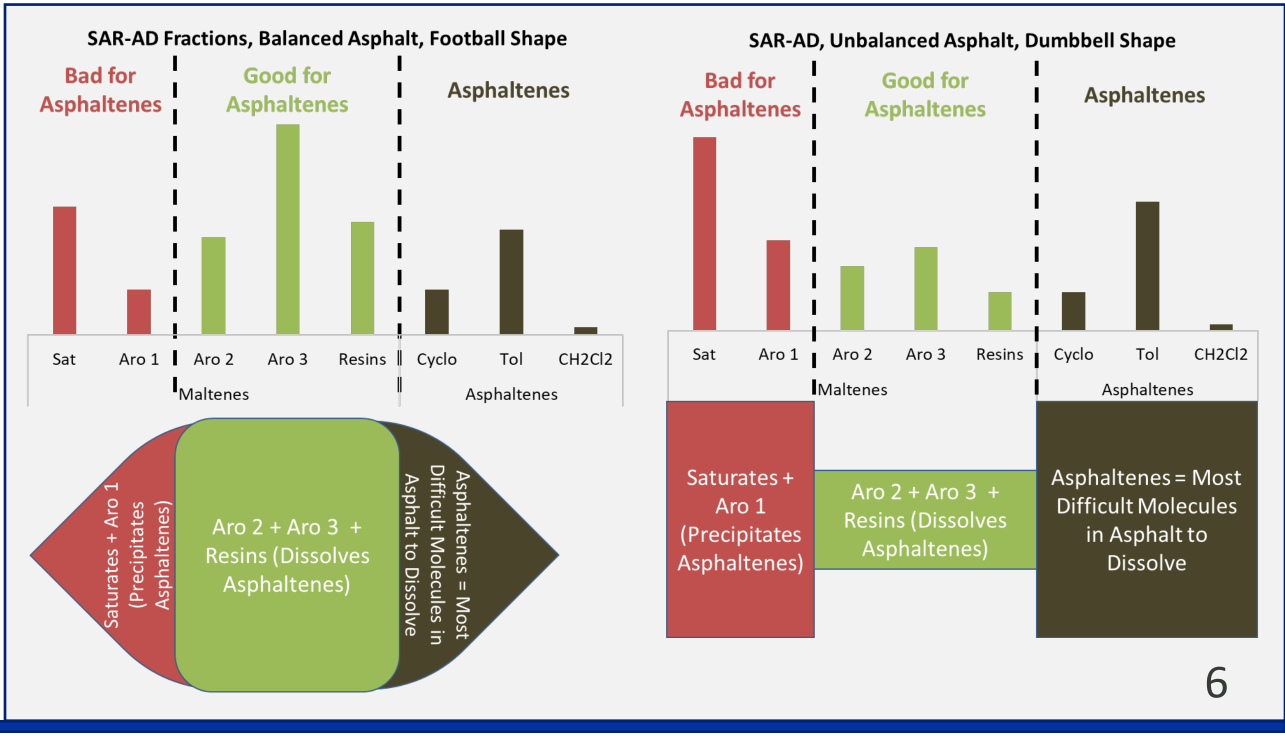
❖ **Processing**
- Partial upgrading
- Pilot and demo-scale plant dev.
- Process integration
- Operational outline
- Analytical

Context-Background

Context - background

- 2020's binders with high variability
  - From crudes (tight oils, heavy crude oils…)
  - From refining blending of residues (SR, AB, SDA, Conversion (IMO 2020)
  - From modification [Polymers and additives such as PPA, FTP, PolyIsoCyanates…]
  - From recycling (RAP/RAS, GTR, plastics...)
  - From bio-origin (recycling agents, WMA additives)
- Chemical complexity
  - Variable continuum of fractions leading to good or poor solubility of asphaltenes
  - Stable "Football" vs unstable "Dumbbell" composition may result in various issues promoting asphalt-based pavement failure
- Very different from SHRP days





Context - background

- Variability and complexity likely to increase with sustainability movement
  - Change in crude oil mix
  - Biorefineries
  - Crude-to-chemicals
  - Residues-to-materials beside asphalt
  - Alternative binders – asphalt free (stay tuned)
  - Supply chain?

- Binder quality impacts performance
  - Current test methods / specs not capturing new binders benefits and drawbacks
  - Rheology not enough
  - Holistic approach required to characterize binders with respect to performance

➢ Need to better consider binder quality to accommodate new binders in BMD environment

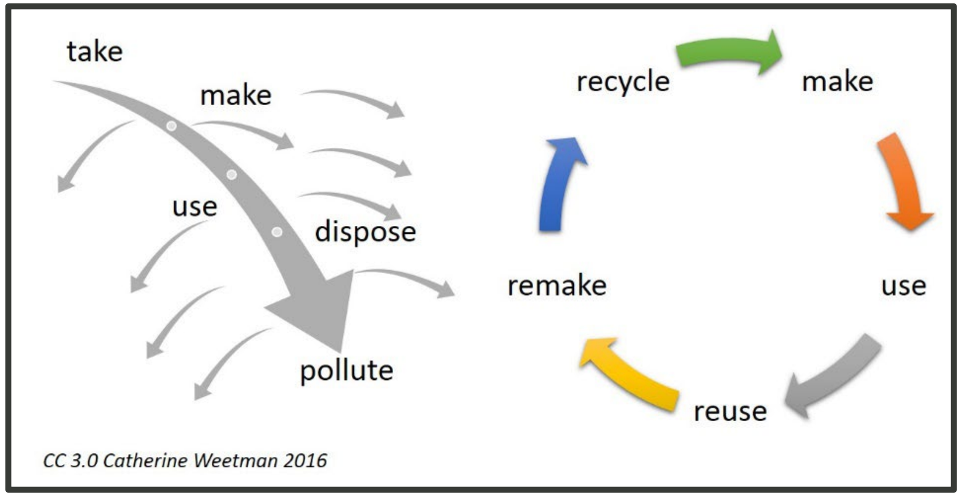
➢ Need to adjust new binder quality to prevent "trashphalt" or linear landfill!

Why WRI^2

Why WRI^2 ?

- Orphan wastes
- Wasting high value original wastes is a waste
- Why just trying to blend waste and see how it performs when knowledge is available to predict the issues…
- Think about solutions for a circular economy using chemist brains!

- Build upon WRI's HC chemistry knowledge, experience and equipment to launch a Waste Re-Engineering Initiative!
- Note: WRI is also part of the NCHRP 9-66 team on Plastic recycling through the dry process – led by NCAT.



https://en.wikipedia.org/wiki/Circular_economy

Future Returns: Investing in the Circular Economy, Feb 9 2021

- 8.6% of 100 billion tons of material a year recycled
- By 2030 up to $4.5 trillion in economic benefit (energy, water, materials, climate change, etc.)
- 10 corporate global bonds dedicated to circular practices (e.g. Owens Corning, $450 million)

https://www.barrons.com/articles/future-returns-investing-in-the-circular-economy-01612907192

What is WRI^2 ?

- *WRI's Waste Re-Engineering Initiative!*
- Started from WRI Internal RD projects (mission of WRI non-profit)
- With a WY angle to identify orphan wastes – but global as well!
- Build upon other projects involving chemical treatment to turn fuel into material

- Goal: Taking wastes, chemically treating / modifying and processing for new and added-value usage for high-volume or high-value markets
- Examples: turbine blades, resins, plastics, RAS, tires… in asphalt
- Terms of Requirements:
    - Simple chemistry – not to develop a COVID treatment!
    - "Cheap"
    - Fairly easy to process
    - Make HSE sound products (IARC monograph in mind)
    - Add-value and Improve performance

Examples

Note: most examples presented at a generic level for IP protection purposes or contract agreement restrictions

Examples: Coal-To-Asphalt

- Coal Extract Modification (Adams / AMAP 2020)

Turn into

+ High Oleic Soybean Oil derivatives

Highly polar and high PG and softening point coal extract

Solubility and rheo properties similar to asphalt

And … PAH compatible with bitumen!

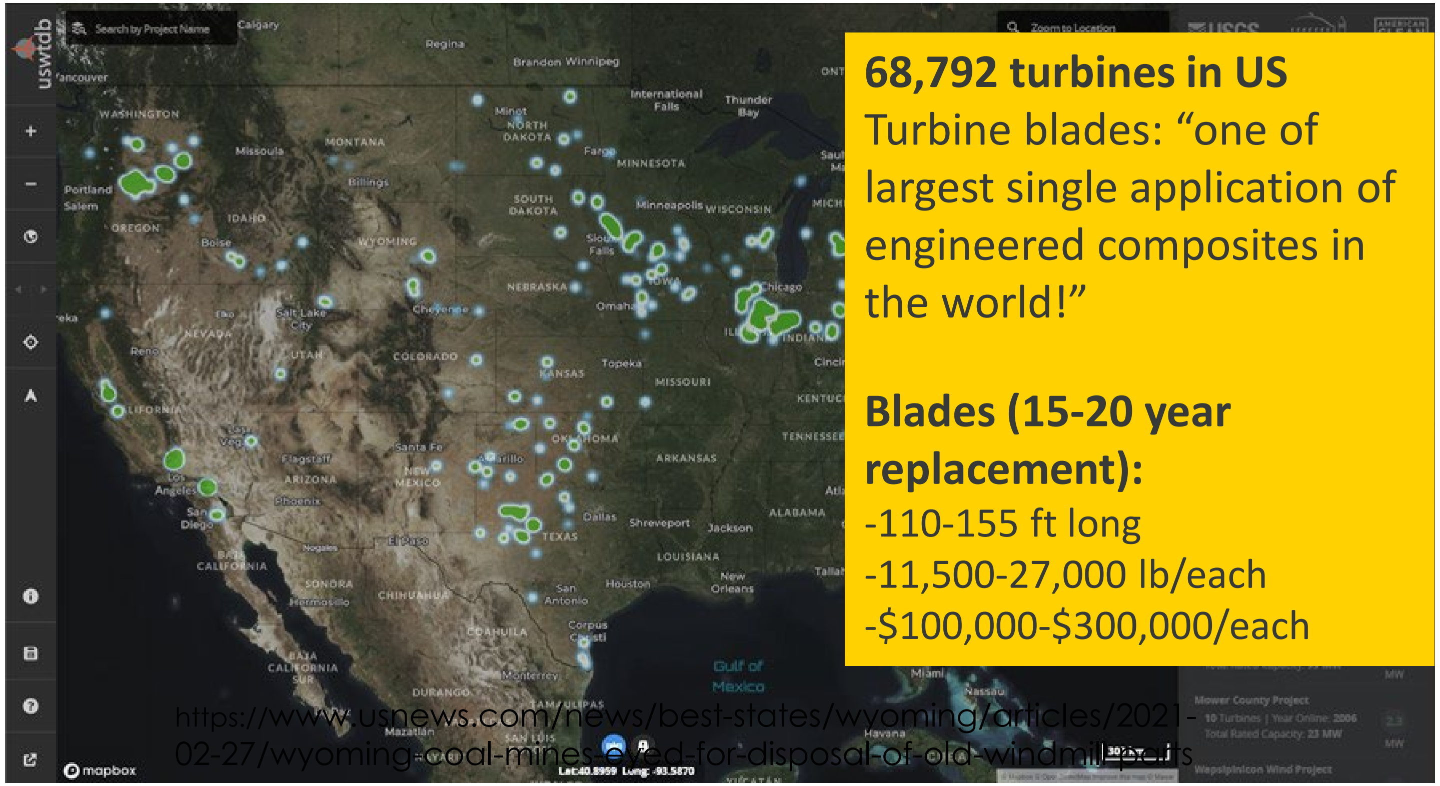
WO 2019/055529 / PCT/US18/50690

- Partners: Western Research Institute, University of Wyoming, School of Energy Resources University of Wyoming and others USB United Soybean Board, Polyco Engineered to Perform

Examples: Wind Turbine Blades

- **Current fate of turbine blades**

https://www.bloomberg.com/news/features/2020-02-05/wind-turbine-blades-can-t-be-recycled-so-they-re-piling-up-in-landfills



https://www.usnews.com/news/best-states/wyoming/articles/2021-02-27/wyoming-coal-mines-eyed-for-disposal-of-old-windmill-parts

68,792 turbines in US
Turbine blades: "one of largest single application of engineered composites in the world!"

Blades (15-20 year replacement):
-110-155 ft long
-11,500-27,000 lb/each
-$100,000-$300,000/each

https://www.compositesworld.com/articles/wind-turbine-blades-big-and-getting-bigger

- **Should turbine blades be landfilled or backfilled into coal mines?**

Examples: Wind Turbine Blades

- **Turbine blade: high value product Epoxy + Glass or Carbon Fiber Composite**
- **Is there value in recycling to contribute to a circular economy?**
  - **Concrete / Road base / Pallets / Reused glass fibers**

Fiberglass

Wood Core

Fiberglass

Note: can be a variety of composites

The WRI Process (patent pending)

❑ Separation Process

Wind turbine blade transportation and storage → **Coarse chunking & sorting** Root vs blade + non fiber-composite components → **Low energy delamination** Remove core material - wood → **Thermochemical digestion** with reactive **bio-based renewable solvents** →

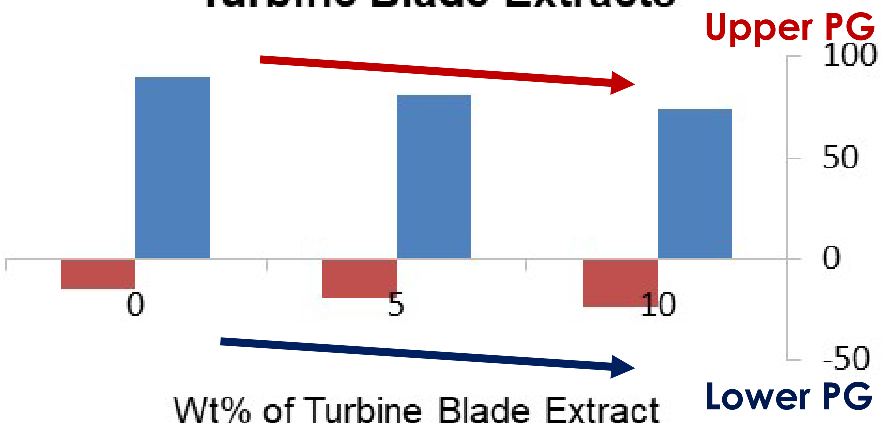
- **Liquid portion form epoxy = Asphalt Recycling Agent**
- **Solid fiber portion from fiberglass or carbon fiber = Asphalt, concrete, construction materials, fiber, filler, fiberglass reuse**

Recycling Agent


+

→


Continuous PG Properties with Turbine Blade Extracts



%RA:	ΔT_c (°C)
0:	-6.9
5:	-5.4
10:	-4.1

Examples: Wind Turbine Blades

Outcome: Asphalt softener or recycling agent (RA) (patent pending)

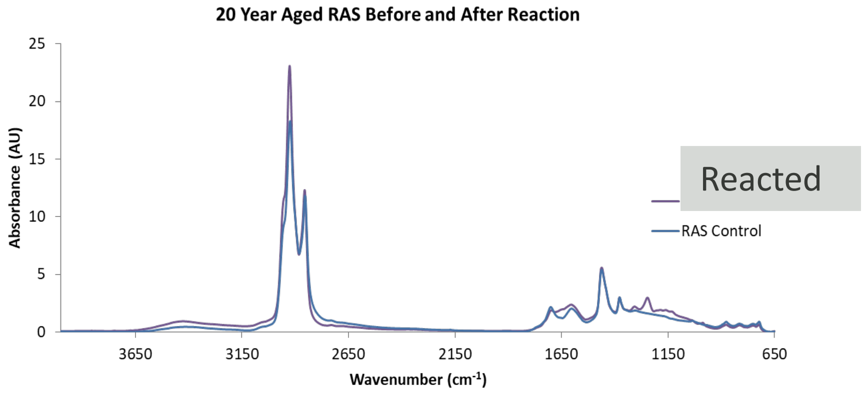
- ❑ Less brittle, more durable asphalt binder
  - ✓ Appropriate rutting resistance (Upper PG)
  - ✓ Improved thermal cracking resistance (Lower PG) and relaxation (T_cm and ΔT_c)
  - ❖ *Note: Relaxation restoration = most difficult target for any additive*
  - ✓ Recycling Agent:
    - ✓ Appropriate chemistry vs. asphalt (SAR-AD)
    - ✓ Resistant to aging

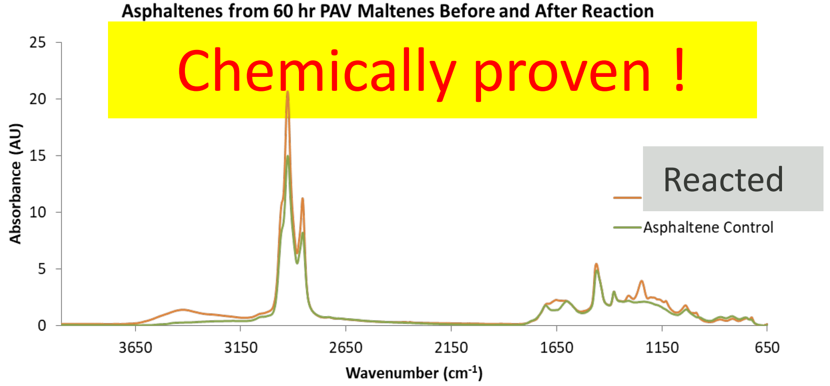
➢ Turbine based recycling agent very promising for many paving applications

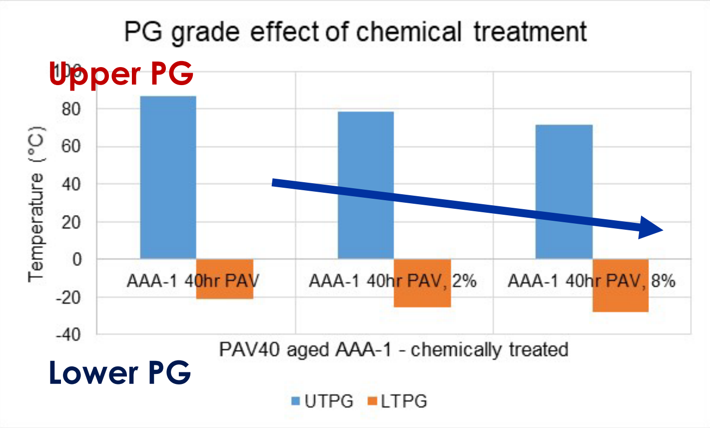
➢ Similar process works for carbon fiber recycling

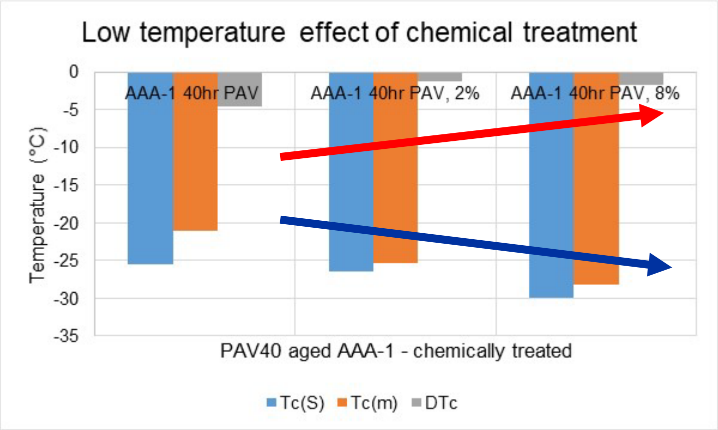
Examples: RAS and RAP

- RAS: very brittle / barely compatible with asphalt
- Concept: chemically treat RAS and/or RAP aged asphalt for use as Recycling Agents or Additives in Roofing and Paving applications
- Next: validation, TEA, scale-up
- (patent pending)









Rheogically proven !

Examples: Plastic Wastes

- Recycle Underutilized Solids to Energy (ReUSE)
  - Funded by ARPA-E
  - Objective: Convert high-energy materials currently landfilled to high-energy liquid products
    - Low-cost, simple, flexible, small-scale regional facilities

Robust feedstock handling
- Discarded polymers
- Liquid blending agents

Pyrolysis
- Thermal decomposition
- Balanced processing conditions

Wide array of products
- Refinery
- Petrochemical
- Building Materials including asphalt additives

WRI patent-pending concept!


Sustainable Asphalt Performance
that Lowers Environmental Impact
23rd Annual Conference
FEBRUARY 1-3, 2022
HOUSTON, TEXAS
AMAP
Association of Modified Asphalt Producers

Summary

Summary

- Plastic / material wastes are ubiquitous and growing but they are not just wastes – very often based on highly sophisticated technologies (turbine blades for example)
- Adding them directly to asphalt applications may be doable but there is a risk of performance degradation, mainly due to poor or lack of compatibility
- Appropriate chemical treatments can improve and add value, and eventually lead to high quality materials for paving or roofing – waste origin dependent
- Chemical treatments can be applied to various reactive feedstocks such as coal or resins to make asphalt like products and respecting HSE constraints
- **Many of the chemistries used under WRI^2 are from renewable carbon sources, making wastes more "green"**
- Proofs of concepts have been obtained on a number of "reactive wastes" to make asphalt additives or even full asphalt replacement
- The road to commercialization is still very long, but this is very important for the future of the paving industry
- Economics are key to success, beside technology readiness
- Both economics and carbon footprints need to be more completely assessed
- Other processes are under development at WRI which could lead to recycle a lot of plastics outside the pavement world, such as refining feedstock applications

- **Stay tuned!**

WRI^2 Perspectives

Perspectives

- WRI is pursuing the WRI initiative on its own funds and/or with partners, optimizing and validating the processes vs. performance and economics and looking at other wastes
- To speed up and value the process, WRI is looking for more partners - US and International - and open for discussion
  - Please contact: jplanche@uwyo.edu and/or jeramie.adams@uwyo.edu
- The recycling of waste and feedstock to-binder trends are likely to continue and amplify - globally
- TRB AFKM 10 and 20 are interested in the alternative binder topic to include in a possible workshop at TRB 2023

jplanche@uwyo.edu
jeramie.adams@uwyo.edu