ASR Holding Company, LLC

MassDEP C&D Webinar Series

Asphalt Shingle Market Development
November 16, 2023

ASR Holding Company, LLC

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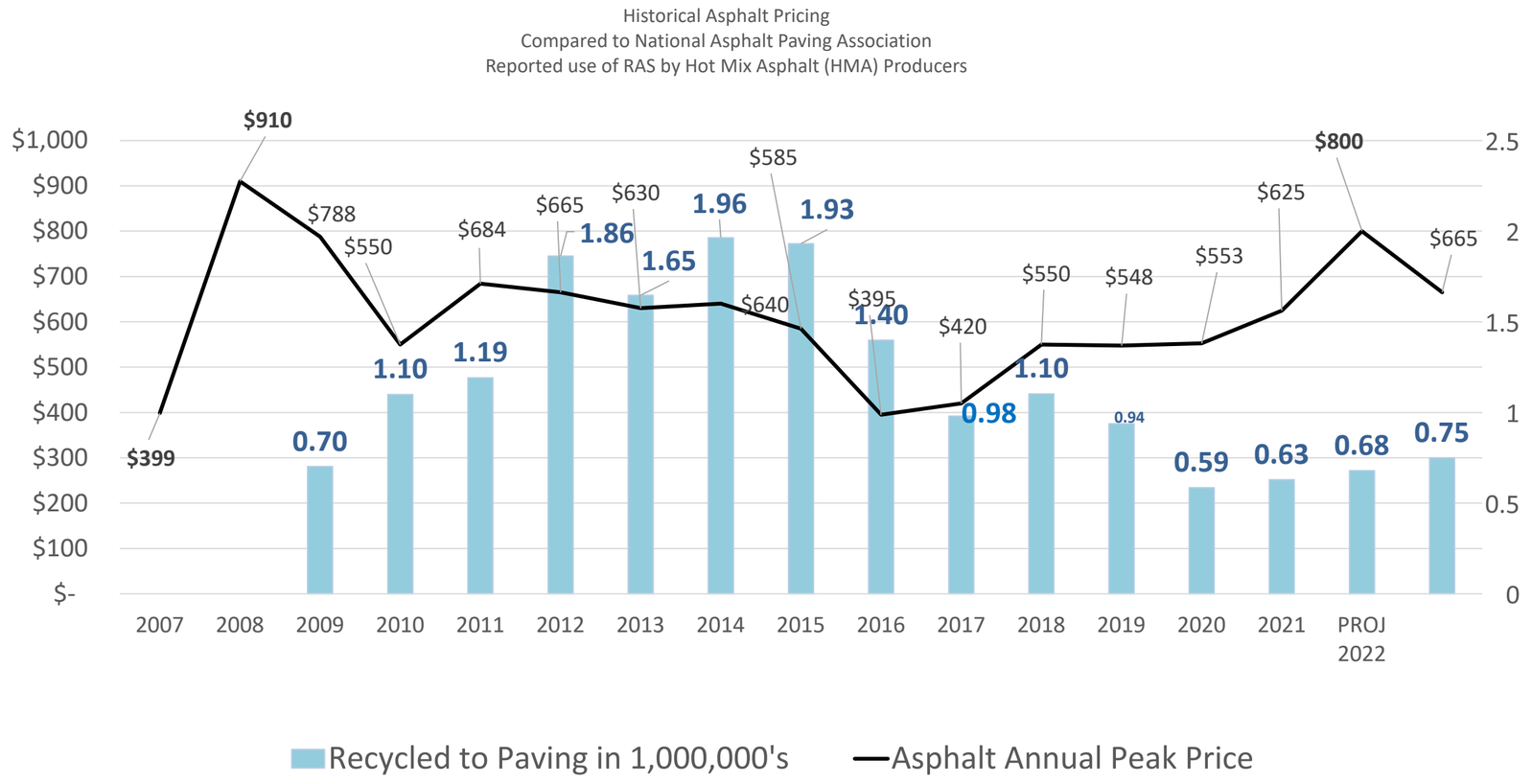
National RAS Use in Roads



The use of Recycled Asphalt Shingles (RAS) in roads has **decreased 68%**[1] from 1,964,000 million tons in 2014 to 630,000 tons in 2021.

Graph shows use compared to asphalt pricing[2].

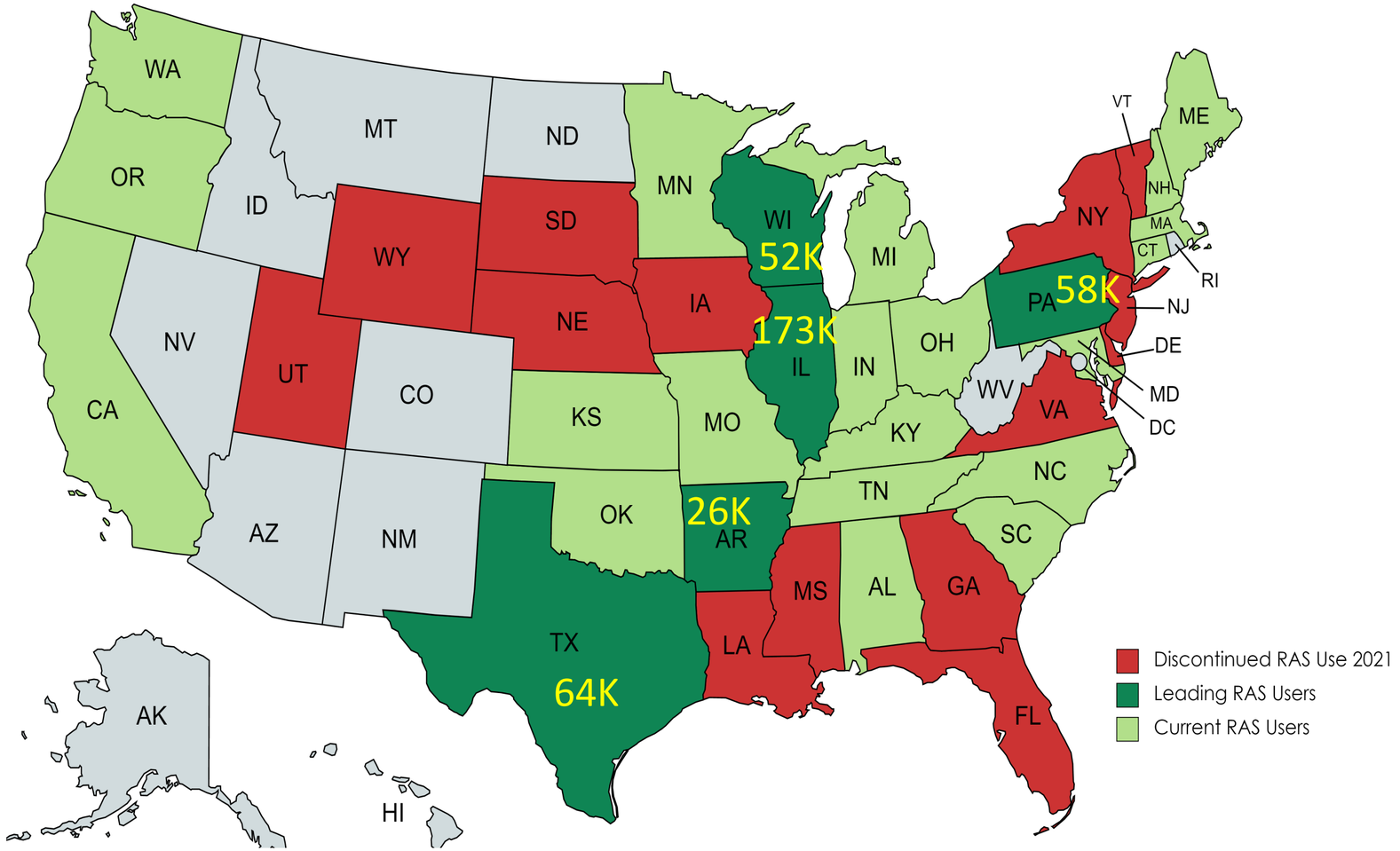
Asphalt pricing has increased.

RAS use is increasing, and new technology is being introduced to rejuvenate use.

[1]Historical Asphalt Pricing Compared to *2021 Survey Asphalt Pavement Industry Survey Recycled Materials and Warm Mix Asphalt usage* Published December 2022

[2]Asphalt Annual Peak Pricing **https://www.mass.gov/lists/massdot-period-price-archives#period-price-archives-(2020---2022)**

RAS Use By State - 2021



66% of RAS Utilization in the USA[3] came from 5 states.

In 24 states, 273M tons of HMA/WMA were installed representing **63%** of a 432.4M tons market.

88% of the HMA/WMA market areas have had **experience with RAS.**

38 states reported use in 2013, which decreased to 24 states from 2013 to 2021.

In these 14 states, 108.5M tons of HMA/WMA were installed representing **25%** of a 432.4M tons market.

[3] *2021 Survey Asphalt Pavement Industry Survey Recycled Materials and Warm Mix Asphalt usage* Published December 2022
Page 28, Table 10, States with Reported RAS Use, 2011-2021

HMA Purchasing Habits

<3/8" Recycled Asphalt Shingles (RAS)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Processed RAS Accepted at the HMA Plant	-	-	-	-	-	-	0.842	0.846	0.311	0.430	0.423	0.278	0.385
Post-Consumer Asphalt Shingles	-	-	-	-	-	-	-	-	0.591	0.534	0.277	0.277	0.230
Manufacturer's Waste Asphalt Shingles	-	-	-	-	-	-	-	-	0.344	0.356	0.334	0.237	0.165
Unprocessed Shingles accepted at the HMA Plant	0.957	1.851	2.500	1.724	1.599	1.684	1.129	1.027	-	-	-	-	-
Used in Other	0.123	0.125	-	0.012	0.005	0.006	-	-	-	-	-	0.055	-
Used in Cold Mix	-	-	-	-	-	-	-	-	-	-	-	-	-
Used in Aggregate	0.006	0.003	0.074	0.073	0.082	0.043	0.009	0.009	0.036	0.050	0.018	-	0.003
Used in HMA/WMA	**0.702**	**1.100**	**1.192**	**1.863**	**1.647**	**1.964**	**1.931**	**1.390**	**0.944**	**1.053**	**0.921**	**0.586**	**0.630**

15.9 Million Tons of RAS

Used in Roads Since 2009

In 2017 the HMA plants accepted .935[4] Millions tons and purchased .311 tons of RAS.

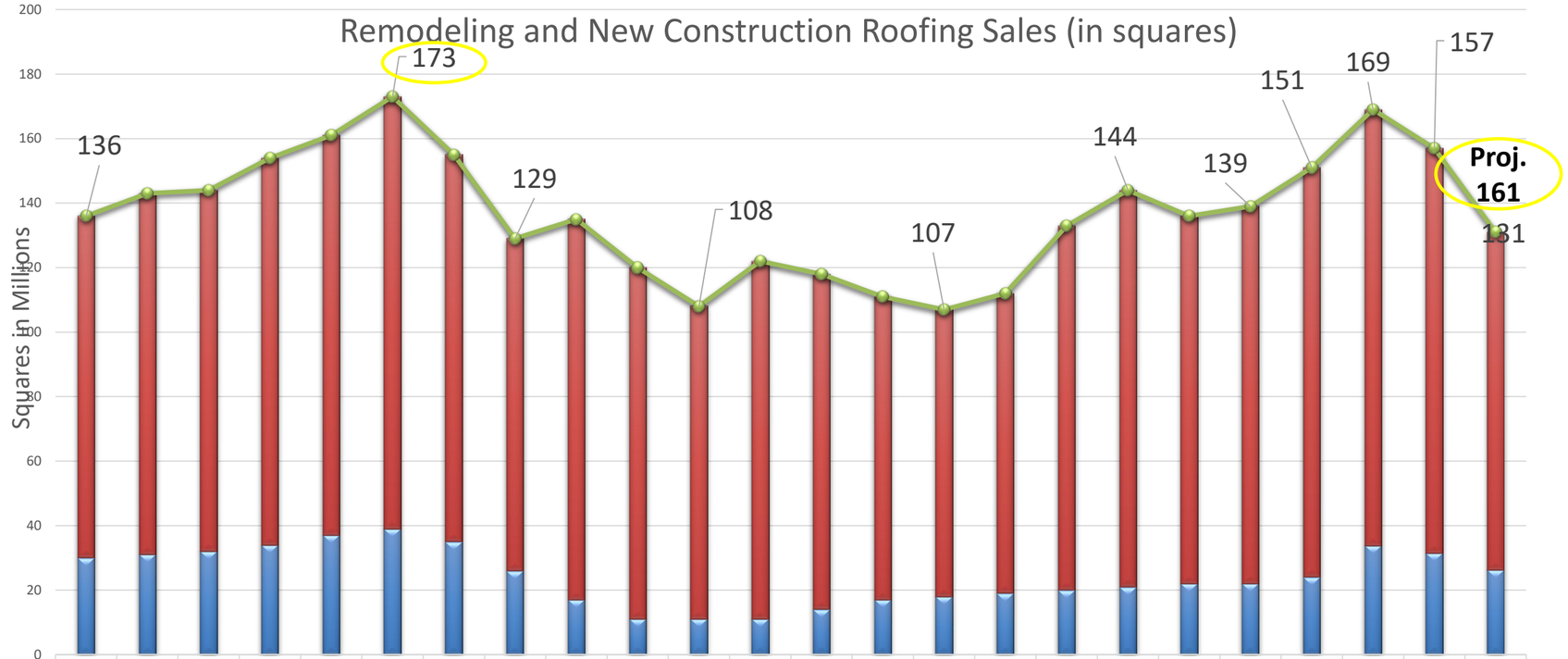
In 2021, HMA Plants accepted .395 Million tons and purchased .385 tons of RAS.

RAS main use is in Hot and Warm Mix Asphalt.

The trend is for HMA plants to purchase processed materials versus accepting waste shingles at the HMA plant creating an **opportunity for the C&D processor.**

[4] *2021 Survey Asphalt Pavement Industry Survey Recycled Materials and Warm Mix Asphalt usage* Published December 2022
Page 24, Figure 9: Comparison of Tons of RAS Accepted and Tons of RAS Used or Landfilled (Million Tons), 2009–2021. Processed RAS Acceptance First Tracked in 2015

USA Roofing Market



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Thru Sept 2023
US Replacement	106	112	112	120	124	134	120	103	118	109	97	111	104	94	89	93	113	123	114	117	127	135	125.6	104.8
New Construction	30	31	32	34	37	39	35	26	17	11	11	11	14	17	18	19	20	21	22	22	24	34	31.4	26.2
US Roofing Sales	136	143	144	154	161	173	155	129	135	120	108	122	118	111	107	112	133	144	136	139	151	169	157	131

Projected Roofing Shipments
161 millions squares[5] EOY 2023

The roofing market's annual sales directly relate to waste stream created.

82.8% of all roofing sold since 2000 in the USA is replacement roofing, creating waste.

[5]2SOURCE: *Asphalt Roofing Manufacturers Association Quarterly Shipping Report* https://www.asphaltroofing.org/arma-releases-third-quarter-2023-report-on-asphalt-roofing-product-shipments/

Waste Stream Analysis

State	2023 Estimated Population	National Sqs. per capita	Estimated Market Size in Sqs.	Estimated Disposal in Tons
Massachusetts	7,029,917	0.48	3,371,260	296,671
Connecticut	3,605,944	0.48	1,729,263	152,175
New Hampshire	1,377,529	0.48	660,607	58,133
Maine	1,362,359	0.48	653,332	57,493
Rhode Island	1,097,379	0.48	526,258	46,311
Vermont	643,077	0.48	308,393	27,139
TOTAL	**15,116,205**			**637,922**

***Notes:**

2023 Estimate source https://data.census.gov/

Squares per capita calculated based on national Asphalt Roofing Manufacturer's Association shipping reports

Disposal in tons rate based on 20% new construction and 220 lbs. per sq. waste ((Mkt Size X 220lbsX 80% remodeling)/2000

Over 250,000 tons of unrecovered asphalt roofing shingles in Massachusetts

In 2017 the HMA plants accepted .935[4] Millions tons and purchased .311 tons of RAS.

In 2021, the HMA Plants accepted .395 Million tons and purchased .385 tons of RAS.

RAS main use is in Hot and Warm Mix Asphalt.

The trend is for the HMA plant to purchase processed materials versus accepting waste shingles at the HMA plant creating an **opportunity for the C&D processor.**

[4] *2021 Survey Asphalt Pavement Industry Survey Recycled Materials and Warm Mix Asphalt usage* Published December 2022
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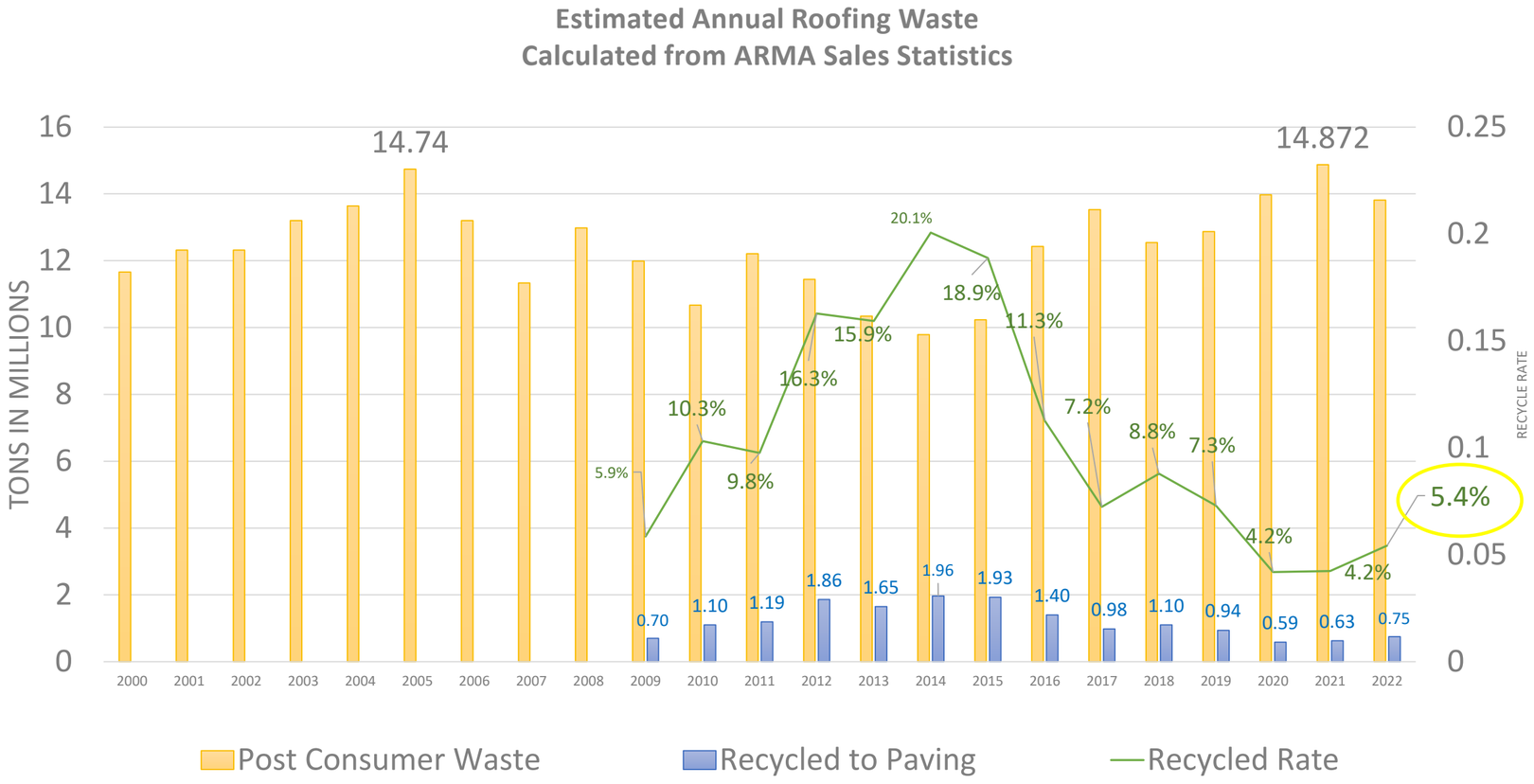
USA Recycling Rate



The estimated annual roofing waste increased 40% from its low in 2014 of 10M tons.

The recycled rate fluctuation is the result of new roofing sales and less use of RAS in the paving industry

Projected 5.4% recycling rate in 2022

SOURCE: Asphalt Roofing Manufacturers Association Quarterly Shipping Report https://www.asphaltroofing.org/arma-releases-third-quarter-2023-report-on-asphalt-roofing-product-shipments/ and 2021 Survey Asphalt Pavement Industry Survey Recycled Materials and Warm Mix Asphalt usage Published December 2022

A | S | R

Processing Shingles for Use in Roads

<3/8” RAS

Description

- Full Shingle reduced to top size 3/8”
- Established use since Brock first published in 1996

Equipment

- Backhoe
- Front end loader
- Sorting Stand
- Single Pass Processing Equipment (w/water)
- Trommel screen

Recycling Center

- Job Trailer
- Weigh scale
- Contractor friendly paved tipping facility and locations
- Processing does not have to be paved… but it is easier to manage nail clean-up

Photo Courtesy of Construction and Demolition Recycling Association https://www.cdrecycling.org/

Loading Full Size Shingles

Recyclers typically choose backhoes for loading processing equipment and front-end loaders for moving finished RAS.

Photo Courtesy of Dan Horton, ASR Systems, Connecticut Facility www.asrsystems.net

Horizontal Shredder (60 tph)

Photo Courtesy of Atascosa Recycling, Ronald Becker https://atascosarecycling.com/ https://www.youtube.com/watch?v=9LFZvsfJr9E

Crushing/ Screening (40-60tph)

Traditional wood processing equipment manufacturers have specialized in shingle grinding equipment.

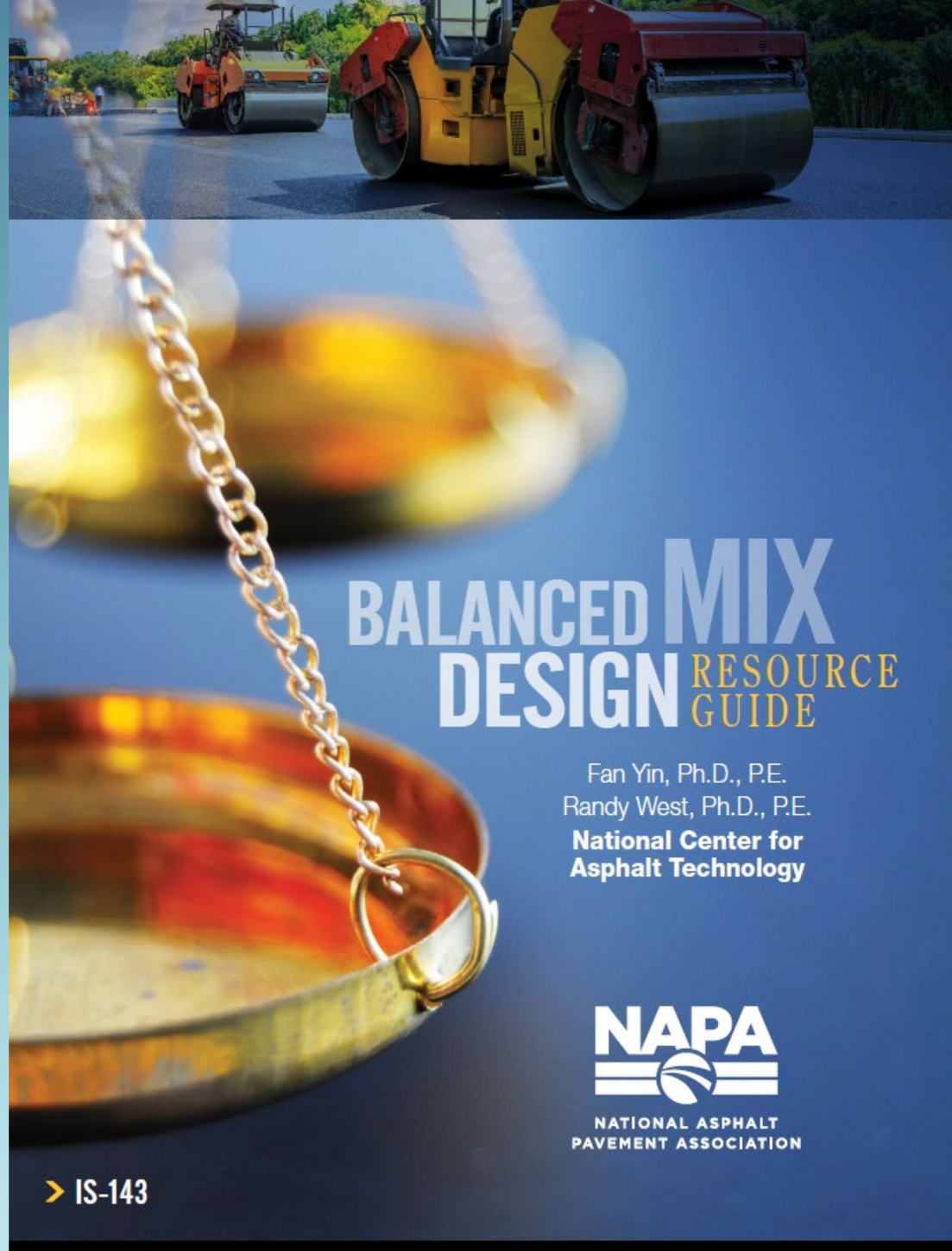
High volume 40-60tph 1-pass from full size to <3/8”.

Combination of outdoor/indoor processing.

Photo Courtesy of Dan Horton, ASR Systems

A | S | R

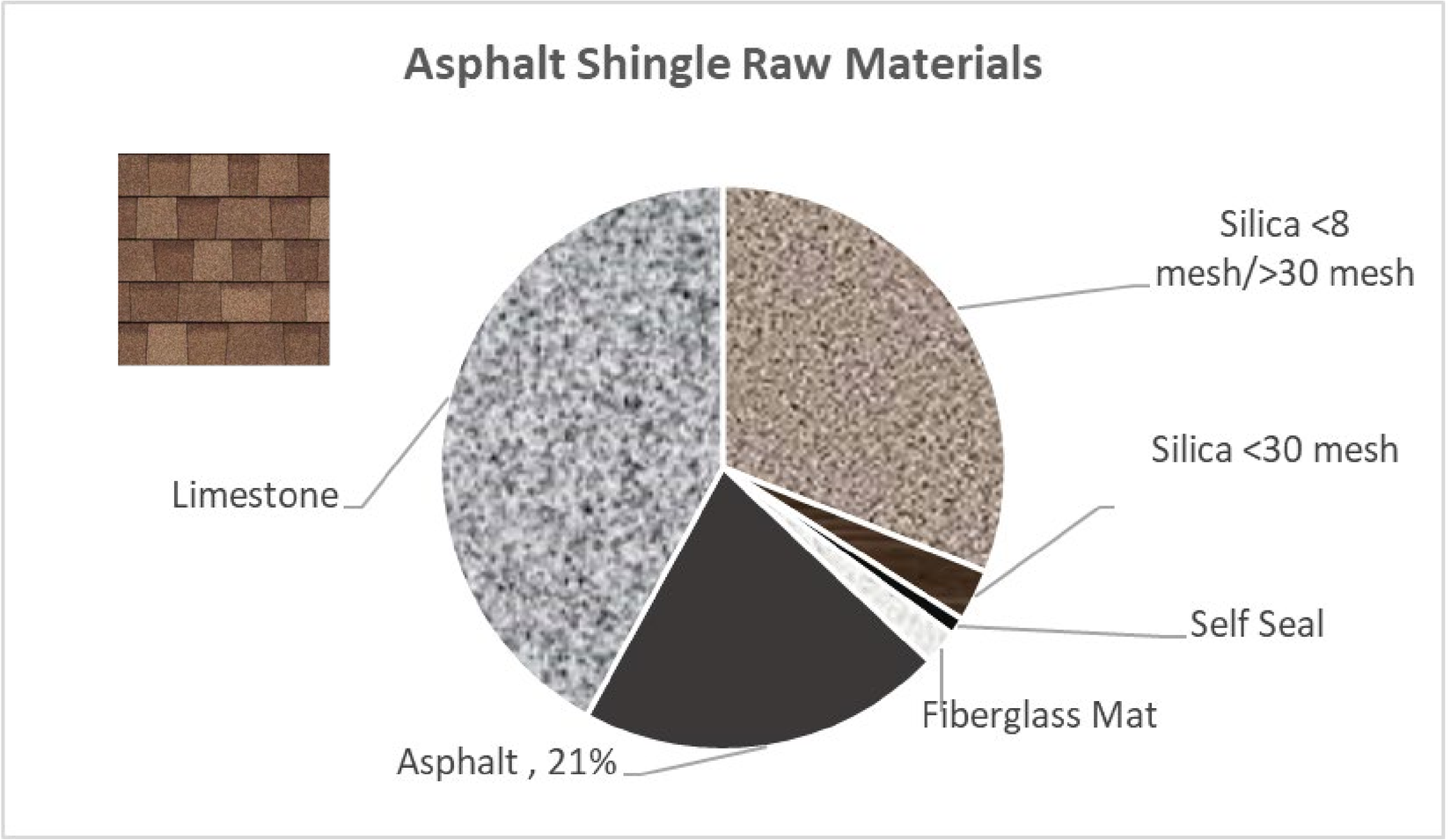
New HMA Solutions



Roofing Shingle Raw Materials

<3/8” RAS is a Combination of aggregates plus 20-22% Asphalt

- Introduced by HMA producers as an aggregate
- Use of RAS is primarily measured by its asphalt properties
- In the most common mix design, Superpave[6], RAS is approved in some states for use from 0-5% of mass
- Key specification measures percentage of mass and Reclaimed Binder Ratio (RBR) as material is often used in conjunction with RAP
- Past mix designs focused on high temperature distress (rutting)
- Low temperature distress or cracking was not addressed in Superpave designs[6]



[6]*Courtney Rice –Senior Engineer, Owens Corning, Recycling with Balanced Mix Design, October 2022 presentation at the CDRA Shingle Recycling Forum*

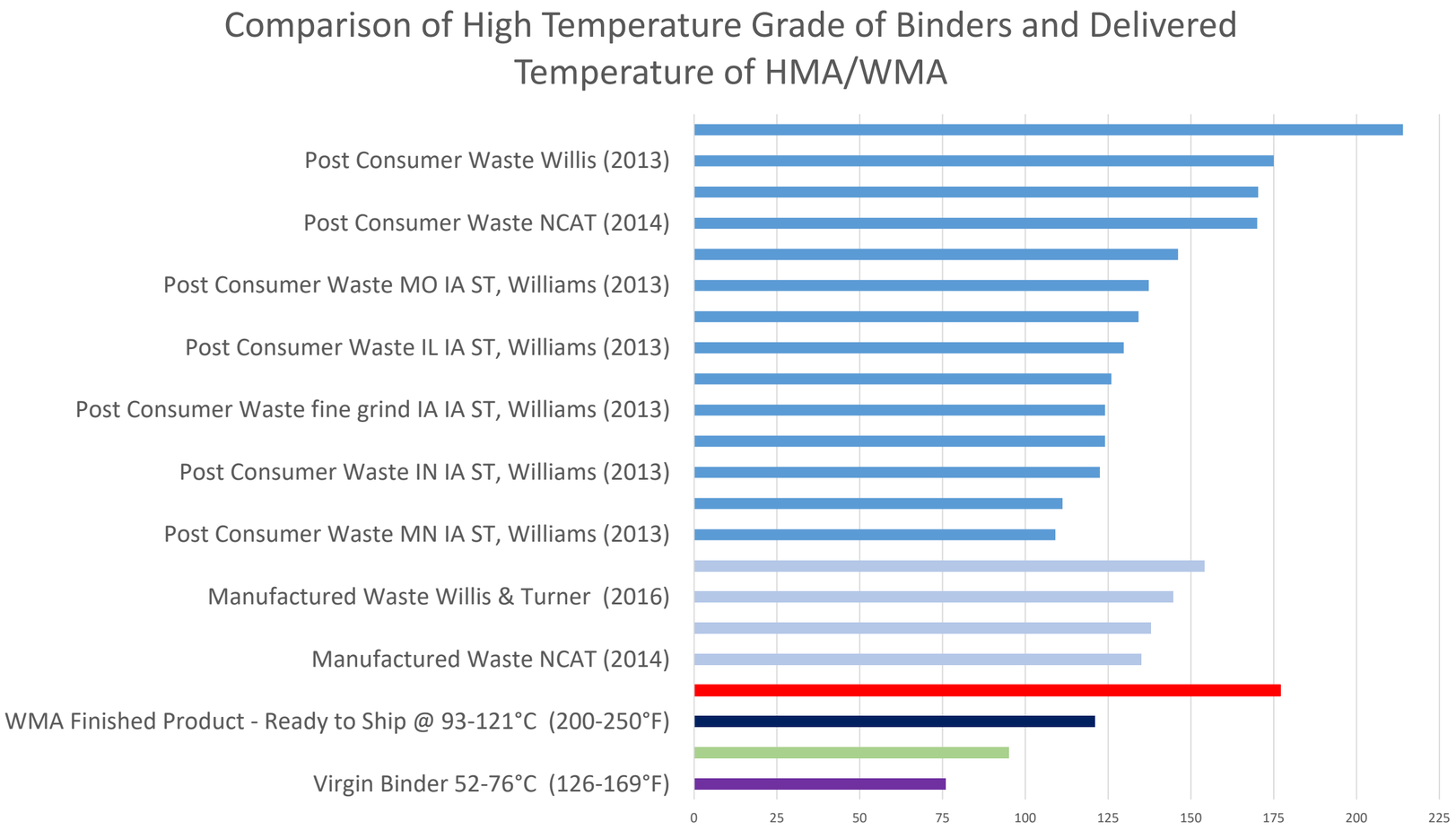
Recycled Roofing Shingle Binder

Performance based testing

- AASHTO PP78-17 (2017) Federal Highway Administration removes binder availability factor
- Arbitrary - minimum voids in mineral aggregate (VMA)[7] ***should be increased by 0.1 percent for every 1 percent RAS*** by weight of total aggregate.
- Calls for **low-temperature binder testing** on the recovered binder.

Performance Testing

- In lieu of blended asphalt binder testing for ΔTc, an agency can implement a **performance test for cracking**. The ΔTc criteria is presented with two allowable methodologies
- An agency develops a statewide or regional **RAS Binder Ratio (RASBR**), or
- Allowable RAS usage is determined on a **mixture-by-mixture basis.**



[5]Identified in M 323. Voids in the mineral aggregate (VMA) are the void spaces between the aggregate particles of the compacted mix. This void space includes the air voids and the effective asphalt content.

Balanced Mix Design

TOP RAS Users

- 37.6% of RAS use in 2021 is in Illinois and Texas

HMA References

- AASHTO PP 78 –Provisional Standard Practice for Design Considerations When Using Reclaimed Asphalt Shingles (RAS) in Asphalt Mixtures

- NAPA IS-143 – Balance Mix Design Resource Guide

Table 1. Summary of State-of-the-Practice on BMD Implementation

BMD Approach	State	Applicable Mixture Type	Rutting Test	Cracking Test	Performance Testing for Production Acceptance?
27.4% of RAS Use in 2021	Illinois	High ESAL mixtures	HWTT	I-FIT	Yes, HWTT for "Pass/Fail"
Approach A	Louisiana	Wearing and binder course mixtures	HWTT	SCB-Jc	Yes, "Pass/Fail"
	New Jersey	Specialty mixtures	APA	OT, BBF	Yes, "Pass/Fail" or Pay Adjustment
10.2% of RAS Use in 2021	Texas	Surface mixtures	HWTT	OT, IDEAL-CT	Yes, "Pass/Fail"
	Vermont	Superpave Type IVS mixtures	HWTT	I-FIT	Yes, PWL
Approach A and D	Virginia	Surface mixtures	APA	Cantabro, IDEAL-CT	Yes, "Pass/Fail"
Approach C	California	Long-life pavement mixtures	FN, HWTT	BBF, I-FIT	Yes, HWTT for "Pass/Fail"
	Missouri	Mainline pavement mixtures	HWTT	I-FIT, IDEAL-CT	Yes, HWTT for "Pass/Fail", I-FIT & IDEAL-CT for Pay Adjustment
	Oklahoma	Superpave mixtures	HWTT	IDEAL-CT	No
Approach D	Alabama	Superpave mixtures	HT-IDT	AL-CT	Yes, "Pass/Fail"
	Tennessee	All mixtures	HWTT	IDEAL-CT	To be determined

ASPHALTICA PELLET IS A NOVEL WAY TO INTRODUCE RECYCLED ASPHALT SHINGLES ("RAS") INTO PAVING WHILE ADDRESSING KEY TECHNICAL CHALLENGES

Challenges of Conventional "Grind Only" RAS

Grinding / Agglomeration:

- ✗ Ground shingles typically compact into large clumps

Operational Challenges at Asphalt Plant:

- ✗ Feed rate is not always consistent
- ✗ Asphalt in end-of-life shingles is too oxidized for hot mix asphalt
- ✗ Asphalt in RAS does not liquefy in normal hot mix process
- ✗ Airborne fiberglass dust creates a potential for worker exposure issues

Asphaltica Pellet Solution

Operational Challenges at Asphalt Plant:

- ✓ Modification of asphalt from patented process that results in a performance grade asphalt allow reduction of virgin asphalt
- ✓ Pellets blend into hot mix asphalt in normal plant operation.
- ✓ Pellets entrap the fiberglass dust reducing worker exposure
- ✓ Pellets store and feed similar to gravel. No agglomeration.
- ✓ Pellets feed at a consistent rate in standard reclaimed asphalt pavement ("RAP") feeders
- ✓ Capable of long-term storage. Pellets can be produced in or off-season, any time of year.
- ✓ Asphaltica pellets are highly water resistant and can be used in variable climate conditions

Asphaltica process can utilize 100% post-consumer, 100% post-industrial and ratios with a mix of the two

Emerging Technologies

Processing Technologies

RAS for Roads

Most Popular Processing Method

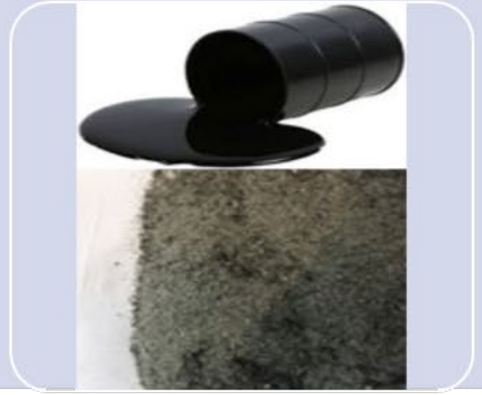
Full size shingle Mechanically reduced to 1-stream of raw materials

ASRH, GAF, Zickell & Harmon Technology

Micronize or Processes to two streams of raw materials

High asphaltic content powder

May match well with GTR technologies



Crown, Horton, Northstar, Sky Quarry and CRS chemical separation technology

Reduction first, then liquid/solid separation using solvents.

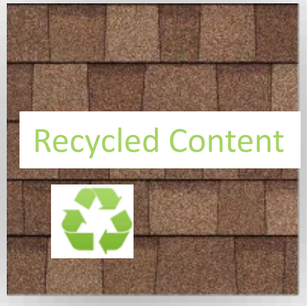
Chemically separates RAS

Two Streams of Raw Materials

Liquid Asphalt &

Solids

Circularity Initiatives



Recycled Content Initiatives

- Asphalt Roofing Manufacturers Association members commit to diversion of 50% by 2035 and 100% by 2050.
- Learnings from circularity technologies will likely spill over to other industries.

Company > Newsroom > News Releases > News Release

NEWS RELEASE

February 09, 2023 | Malvern, Pennsylvania United States

SAINT-GOBAIN ACQUIRES ASPHALT SHINGLE RECYCLING TECHONOLOGY, ADVANCING ITS COMMITMENT TO WASTE REDUCTION

certainteed SAINT-GOBAIN

ASPHALTICA ASPHALT INNOVATIONS

Saint-Gobain North America, through its building products subsidiary CertainTeed Roofing, has acquired the rights to technology from recycling partner Asphaltica that will allow the company to recycle asphalt shingle waste, diverting it from landfill and furthering the company's commitment to creating a circular economy in its production of roofing shingles.

The proprietary technology from Asphaltica will allow Saint-Gobain to pelletize both post-industrial and post-consumer shingle waste. This process creates pellets out of ground shingles that blend well in hot mix asphalt and are an ideal component in an asphalt paving mix. In

SAINT-GOBAIN IN NORTH AMERICA
- HISTORY
- DOING BUSINESS WITH US
- LIVING LABORATORY

CULTURE AND VALUES
- OUR PRINCIPLES
- DIVERSITY & INCLUSION
- EMPLOYEE RESOURCE GROUPS
  - APAN NETWORK
  - EARLY CAREER NETWORK
  - LGBTQ NETWORK
  - VETERANS NETWORK
  - WOMEN'S NETWORK
  - LEAD NETWORK

CORPORATE SOCIAL RESPONSIBILITY
- SUSTAINABILITY
  - RELATIONSHIPS FOR SUSTAINABILITY
  - PROGRAMS FOR SUSTAINABILITY
  - COMMITMENTS TO SUSTAINABILITY
- OUR FOUNDATION
- YOUTHBUILD PARTNERSHIP
  - BUILDING OUR FUTURE

GAF

YOUR HOME RESIDENTIAL ROOFING COMMERCIAL ROOFING BUILDING SCIENCE IN YOUR COMMUNITY

RESIDENTIAL ROOFING

Recycled Shingles are Keeping Asphalt Out of Landfills

By **Karen L Edwards** 12-17-2022

In March 2022, the first-ever roof constructed from shingles partly composed of recycled asphalt was installed on a Florida home. The groundbreaking shingles were developed by GAF using recycled asphalt shingle (RAS) technology and have received several recognitions. They were named by Popular Science as one of the Best of What's New for the Home, and by Fast Company as one of the "Next Big Things in Tech" in the "Sustainability" category, bringing "some welcome circularity to the roofing economy" by allowing new shingles to be made using material reclaimed from old ones.

An Environmental Game-Changer

ARMA Releases Statement on Recycling Asphalt Roofing Materials

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ASPHALT ROOFING MANUFACTURERS ASSOCIATION

Forest Hill, MD (May 10, 2022) – The Asphalt Roofing Manufacturers Association (ARMA) Board of Directors announced that it has adopted a position on the recycling of asphalt roofing materials:

ARMA Statement on Recycling of Asphalt Roofing Materials

The industry goals are to reduce landfill disposal of asphalt-based roofing materials to 50% by 2035 and to approach 0% by 2050.

To accomplish these goals, ARMA will foster and promote responsible, economically feasible, and sustainable circular economy options to recycle asphalt-based roofing materials and enhance the long-term viability of asphalt roofing as the preferred roofing material.

"ARMA recognizes that industry initiatives are best achieved when there are common goals, especially in efforts involving sustainability and recycling," stated Reed Hitchcock, ARMA Executive Vice President. "Increased recycling of asphalt roofing materials will further improve our industry's circularity and overall environmental footprint."

ARMA's vision and mission is to be an association committed to the long-term sustainability of the asphalt roofing industry and to advocate and advance the interests of the asphalt roofing industry by leveraging the collective expertise of its members.

For more information about ARMA, visit asphaltroofing.org.

###

· ***Northstar approved for award of up to $7,088,856 of a total of $50 million committed by ERA as part of its 'Circular Economy Challenge' launched in March 2022***

· ***$7,088,856 in funding for Northstar's Empower Calgary Facility represents 100% of Northstar's request to ERA***

VANCOUVER, British Columbia – February 13, 2023 – Northstar Clean Technologies Inc. (TSXV: ROOF, OTCQB: ROOOF) ("Northstar" or the "Company") is pleased to announce that Northstar's planned scale up facility in Calgary, Alberta (the "Empower Calgary Facility") has been approved for a non-repayable government grant of up to approximately $7.1 million by Emissions Reduction Alberta ("ERA"), an Alberta-based government entity funded by the Government of Alberta.

Mr. Aidan Mills, President &CEO and Director of Northstar, stated, "As a sustainable clean technology company, we are beyond excited that ERA has selected our Company for funding of up to approximately $7.1 million in non-repayable government grants. We applied for $7,088,856 for funding the Empower Calgary Facility and we have been approved for 100% of our request. We believe in ERA's long-term mandate to reduce GHG emissions and grow Alberta's economy by accelerating the circular economy and the development and adoption of innovative technology solutions. We are thankful to ERA for its support towards fulfilling our mission of becoming a leader in the recovery and reprocessing of asphalt shingles in North America and we look forward to our partnership and collaboration."

Mr. Justin Reimer, CEO of ERA, stated, "A more sustainable, diversified provincial economy requires using our resources more wisely, we need to think about waste as a resource rather than a cost. Northstar's technology will divert end-of-life asphalt roof shingles from Alberta's landfills and turn them into valuable products, delivering economic and environmental benefits in the process. It establishes a circular economy approach that, if successful, could be exported and deployed across North America."

The lead applicant organization is Empower Environmental Solutions Calgary Ltd., a wholly owned subsidiary of Northstar, and the net proceeds received by the Company from the government grant will be used to further design, construct and commission the Empower Calgary Facility.

Creating a sustainable shingle

, director of sustainability for Owens Corning, discusses the company's recently launched shingle recycling facility in Indianapolis.

Photo from C&DR photo archives

ALEX KAMCZYC | JANUARY 26, 2023

Last year, Owens Corning, a Toledo, Ohio-based construction materials company, launched a recycling pilot facility for asphalt shingles in Indianapolis. The company says the pilot will drive its work to reclaim asphalt shingle components and repurpose the raw materials into new shingles.

The pilot was launched with ASR Systems, a producer of recycled asphalt shingles based in Barrington, Rhode Island; CRS Reprocessing Services, an industrial fluid and solid material management company based in Louisville, Kentucky; and Indiana Shingle Recycling, based in Indianapolis. Owens Corning says its goal is to recycle 2 million tons of shingles annually in the U.S. by 2030.

Construction & Demolition Recycling recently spoke with Mark Leo, Owens Corning's director of circular economy, about the pilot program, the partnership that made it possible and the company's circular economy goals.

***C&DR*: Can you explain what the pilot project seeks to do?**

Mark Leo (ML): Owens Corning, with ASR Systems and CRS Reprocessing Services, is piloting a way to break down shingles into their components and utilize those components to produce new shingles and other products. While this work has been proven at a lab scale, the construction of the pilot on the grounds of Indiana Shingle Recycling is the next step toward commercialization.

While this work has been proven at [a] lab scale, the construction of the pilot on the grounds of Indiana

Research - VTrans

Recycled Asphalt Shingle as an Full Depth Reclamation Mechanical Stabilizer

- October 2023 – September 2025
- VTRANS
  - Callie Ewald, Geotechnical Engineering Manager
  - Ian Anderson, HMA Materials Manager
- UNH
  - Eshan V. Dave, University of New Hampshire, PI
  - Jo E. Sias, University of New Hampshire
  - Gabriele Tebaldi, University of New Hampshire

VERMONT AGENCY OF TRANSPORTATION

FACT SHEET

RAS as an FDR Mechanical Stabilizer

PROJECT TITLE
Recycled Asphalt Shingles as an Full Depth Reclamation Mechanical Stabilizer

STUDY TIMELINE
October 2023 – September 2025

INVESTIGATORS
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VTRANS CONTACTS
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KEYWORDS
Recycled asphalt shingles, pavement rehabilitation, full-depth reclamation, by-product, sustainability, reuse.

FUNDING
VTRC023-603
$135,898

University of New Hampshire

More information about the VTrans Research Program, including additional Fact Sheets, can be found at: http://vtrans.vermont.gov/planning/research

Introduction or Problem Statement

The use of recycled asphalt shingles (RAS) in transportation infrastructure has been extensively studied throughout the United States and elsewhere. An impediment in the use wide-spread use of RAS in asphalt concrete has been the increased premature cracking potential of such mixtures due to the aged and brittle nature of asphalt binder in RAS. This has resulted in restrictions on RAS usage in hot- and warm-mixed asphalts by many agencies. The Vermont state law (10 V.S.A. § 6605m) requires that asphalt shingles, predominantly generated as "Architectural Waste", be recycled. Due to concerns associated with their usage in asphalt concrete layers of pavement structures, their use within lower pavement layers needs to be explored.

The use of full-depth reclamation (FDR) for the rehabilitation of flexible pavements is preferred by many transportation agencies, including VTrans, due to cost and environmental benefits. Both are usually realized due to the "in-place" nature of the FDR process that does not require large quantities of materials to be transported off-site which in turn lowers costs and fuel usage as well as associated emissions. Often Portland and other hydraulic cements, emulsified asphalt, foamed asphalt and combinations of these materials are used as stabilizing agents in FDR to improve its structural contribution to the pavement and improve longevity of roadways using it. Most of the stabilizing agents used in FDR have high costs and carbon footprints. Due to the presence of asphalt binder, fibers and aggregate, RAS has potential to provide a degree of mechanical stabilization to the FDR layers. If RAS can be used to achieve similar stabilizing effects as non-recycled products, the lower costs and high environmental benefits of FDR can be further improved and simultaneously use of RAS in pavement infrastructure can be realized without performance concerns. To realize this goal of using RAS in FDR, two critical questions will be addressed in this research: (1) Can RAS be utilized in "as-is" condition from when it is generated as architectural waste or is there need for processing it to resize it? (2) Does RAS provide mechanical stabilization effects to FDR?.

Left: As produced architectural waste shingles; Right: resized processed waste shingles [image sources: Wisconsin Dept of Natural Resources and North Carolina Department of Environment Quality]

Methodology or Action Taken

This research study will undertake a laboratory experimental campaign and corresponding analysis to determine whether RAS can be utilized in "as-is" or resized condition to serve as stabilizing agent within FDR. This question is critical to answer since additional processing steps would have cost and logistics implications with respect to usage of RAS. A hypothesis is that the FDR process can provide some crushing effort towards breakdown of waste shingle sheets. To evaluate this hypothesis and to determine feasibility of using RAS in FDR an assessment is necessary to determine constructability of FDR stabilized using RAS, specifically in terms of compactability. This study will develop recommendations for determining suitable dosage of RAS that can be accommodated within FDR to realize appreciable mechanical stabilization effects. Further, it will also explore the use of recycling agents to provide additional stabilizing effect of RAS. Lastly, to quantify the stabilizing effects of RAS, the outcomes of laboratory characterization will be used in a pavement design and analysis system to determine life cycle cost benefits.

The laboratory experimentation effort will conduct mechanical characterization of RAS-stabilized FDR along with unstabilized control materials through measurement of resilient modulus and shear strength measurements. RAS will be evaluated for environmental contaminants, specifically, for PCB, PFAS, and PAH, including the use of Synthetic Precipitate Leaching testing (SPLP).

Conclusions or Next Steps

This project is at its initiation stage, the very immediate next step will be to conduct a comprehensive review of literature, develop experimental designs and sample materials from VTrans FDR projects for use in laboratory characterization.

Potential Impacts and VTrans Benefits

Results of this study will be in the form of recommendations for VTrans to revise FDR construction and material specifications to include RAS. The research results will also provide VTrans with quantitative measures associated with mechanical stabilization potential of RAS in FDR. Further, as a first step to implementation of using RAS in FDR, VTrans will have informaiton on optimal dosages as well as lab procedures that should be used to validate the dosage amounts. As an added outcome, this project will provide recommendations on suitable roadway rehabilitation candidate projects where RAS stabilized FDR would provide positive life cycle cost and pavement performance benefits. Ultimately, the results of this project will enhance the understanding of the risks or benefits associated with utilizing recycled products in FDR layers and their potential to impact pavement performance. This will ensure VTrans has the information needed to make prudent decisions regarding their asphalt pavements, as they strive to develop treatments that require less frequent maintenance and/or rehabilitation while lowering life cycle costs. The research project will conduct preliminary life cycle cost analyses comparing pavements rehabilitated using unstabilized FDR with those using RAS stabilized FDR. This research will also provide VTrans with a better tool to evaluate new materials and additives (e.g. recycling agents) resulting in improved materials. Use of RAS in FDR will allow VTrans to support Vermont's initiatives towards recycling additional construction waste materials and open up a new market for RAS in areas where inclusion in HMA is limited.

https://vtrans.vermont.gov/planning/research/projects/RASinFDR

Research – Rejuvenators & Modifiers

NCAT Report 21-03

September 2021

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Phase VII (2018-2021) NCAT Test Track Findings

Randy West, David Timm, Buzz Powell, Nam Tran, Fan Yin, Benjamin Bowers, Carolina Rodezno, Fabricio Leiva, Adriana Vargas, Fan Gu, Raquel Moraes, Mostafa Nakhaei

ELSEVIER

Construction and Building Materials

Volume 208, 30 May 2019, Pages 543-553

Construction and Building MATERIALS

Durability of bio-modified recycled asphalt shingles exposed to oxidation aging and extended sub-zero conditioning

Daniel J. Oldham [a], Amirul Islam Rajib [a], Albert Onochie [b], Elham H. Fini [c]

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Abstract

The use of recycled asphalt shingles (RAS) in pavement construction has received significant attention due to its economic and environmental advantages. However, asphalt binder in RAS is significantly aged and requires modification before application to ensure it does not compromise pavement performance. The paper introduces a novel

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP RESEARCH REPORT 927

Evaluating the Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

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https://vtrans.vermont.gov/planning/research/projects/RASinFDR

Increasing Recycling Rates

Recycled Roofing End Markets

HMA

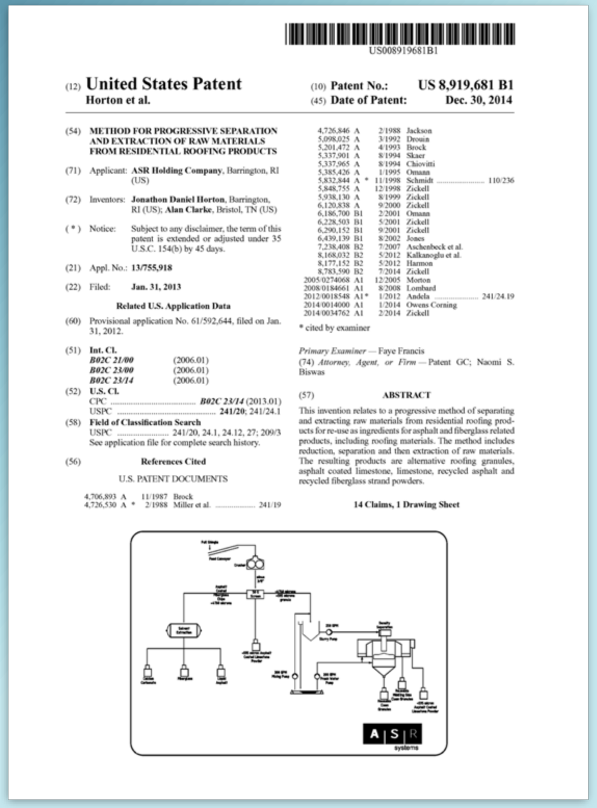
- **Consider Balanced Mix Design**
- **Reduce Carbon Footprint with RAS Use**
- **Review Pelletizing Technology**

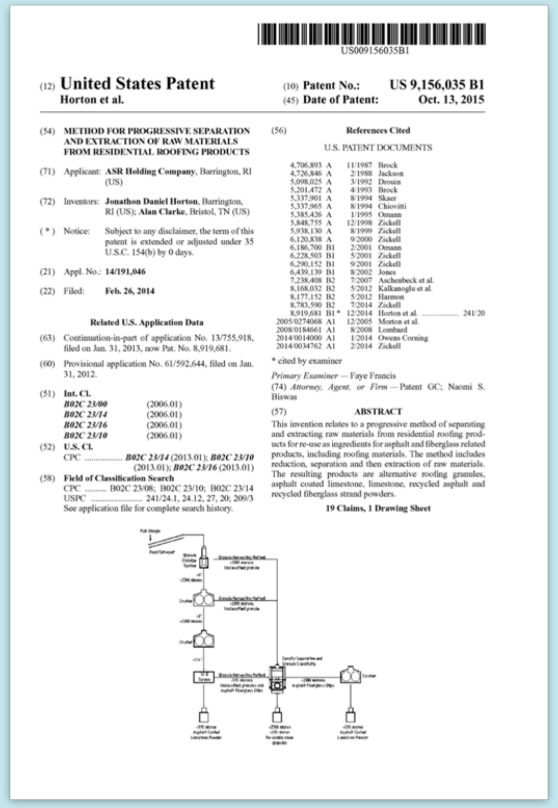
Circularity

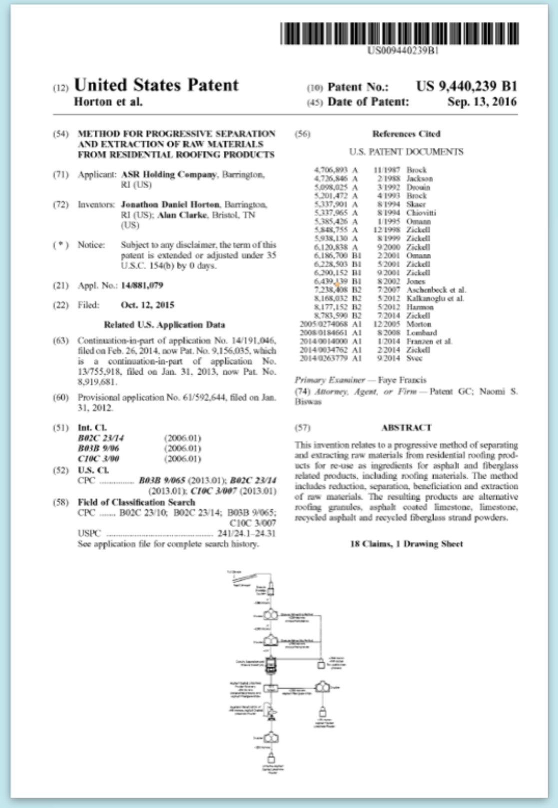
- **Research Circularity Opportunities and Existing Patents**

New End Markets

- **Understand new technologies and opportunities for high volume end markets**







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Thank you

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