Combining EPDs with Performance Testing

Evaluating the Environmental and Mechanical Performance of Asphalt Mixtures at the Project Level

66th Annual PAPA Conference – Richard Steger

Acknowledgements - PA EPD Graphics

Parajuli

Mishra

COLLEGE OF ENGINEERING
THE CHARLES E. VIA, JR. DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
VIRGINIA TECH.

COLLEGE OF ENGINEERING
THE CHARLES E. VIA JR. DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
VIRGINIA TECH.

Deb Mishra, Ph.D., P.E.
Associate Professor
debmishra@vt.edu

301 D-2, Patton Hall
750 Drillfield Drive
Blacksburg, VA 24061
o: 540-231-1894
c: 806-252-8558

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

VIRGINIA TECH
TRANSPORTATION
INSTITUTE

Mishra Research Group
Center for Sustainable and Resilient Infrastructure
Virginia Tech | Virginia Tech Transportation Institute

ingevity

Agenda

1. Timeline - Introduction
2. Project Location
3. Mixture EPDs
4. Rejuvenated Mix Performance
5. Mix Comparison
6. Summary
7. Conclusions

A Long Time Ago in Pavement Innovation...

It is a period of rapid change in asphalt *technology. Sustainability and performance are* at the forefront as *engineers seek* to balance recycled *content with durability* and environmental *responsibility.*

On Dutch Ridge Road, a field application is *underway—testing* high RAP mixtures with *rejuvenators, pushing* the boundaries of *what's possible* in pavement design.

Timeline

January 17, 2024

Rejuvenated High RAP Mixtures

A Field Application - design, lab & field performance, and benefits of using recycling agents to improve sustainability and pavement quality.

February 19th , 2025

Effectiveness of Recycling Agents in High RAP Plant Produced Asphalt Mixtures -Evaluates field & lab performance of asphalt mixtures with high RAP using 2 types of recycling agents, demonstrating effective service & test results after one year in service.

January 21, 2026

From Plant to Pavement: Using EPDs and Performance Tests to compare Asphalt Mixtures

2024-Rejuvenated High RAP Mixtures Field Application

- **Background & Motivation:** explored the use of rejuvenators to enable higher RAP content in asphalt mixtures, aiming to improve sustainability, reduce costs, and maintain or enhance pavement performance.
- **Technical Foundation:**
  - Rejuvenators help rebalance the asphaltene-to-maltene ratio in aged binders, reducing brittleness and cracking potential.
  - Types include petroleum-based and plant-based (bio-based) agents.
  - Dosage and need for rejuvenators depend on RAP/RAS content and binder properties.
- **Field & Laboratory Studies:**
  - Compared conventional (15% RAP) and high-RAP (35%) mixes, using different rejuvenators (Cargill Anova, Ingevity Evoflex).
  - Laboratory and field-produced mixtures were evaluated for rutting and cracking resistance, density, and long-term durability.

ingevity

2024-Rejuvenated High RAP Mixtures Field Application

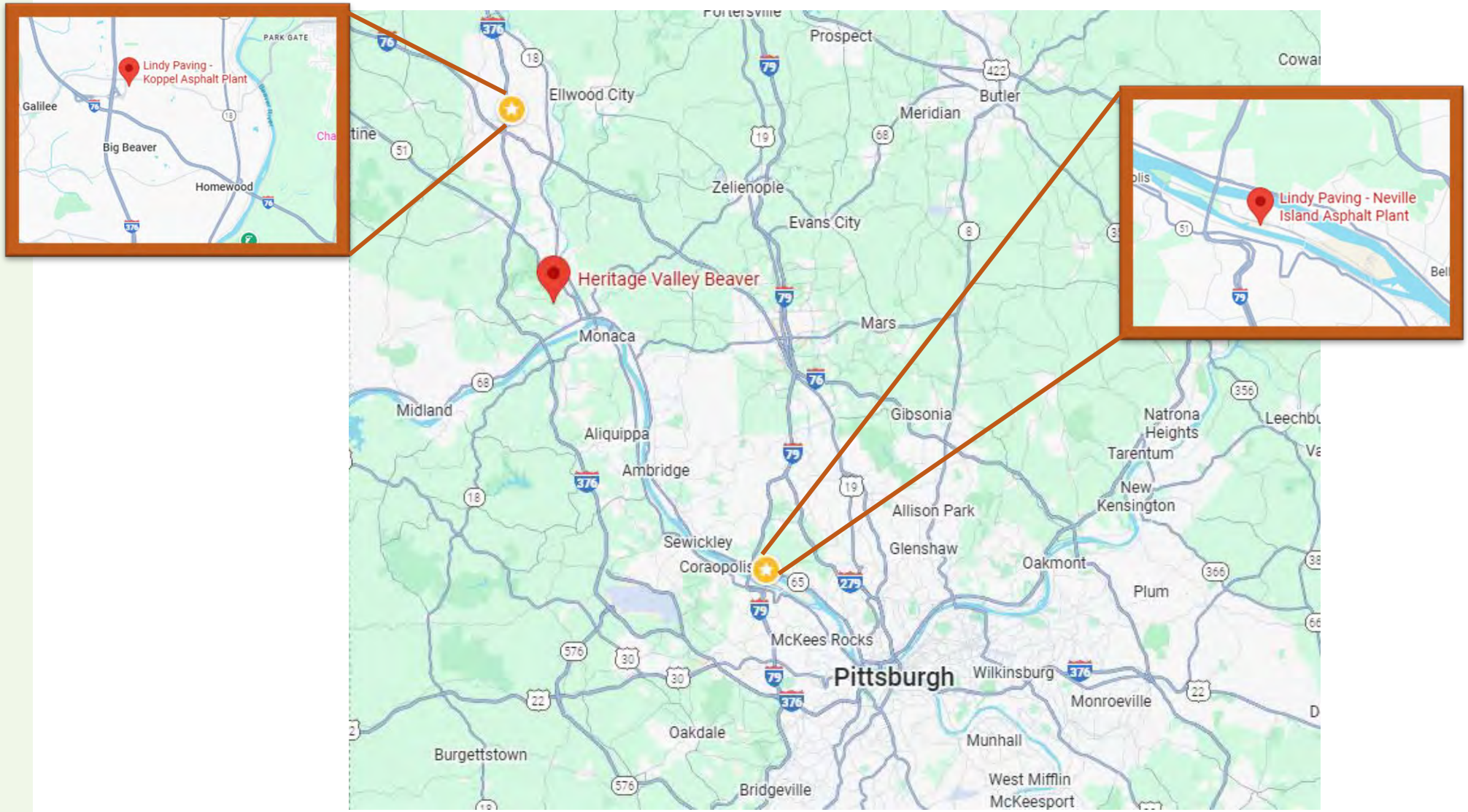
- **Key Findings:**
  - High-RAP mixes with rejuvenators achieved comparable or improved rutting and cracking performance versus conventional mixes.
  - Proper selection and dosage of rejuvenators are critical for balancing performance and sustainability.
- **Conclusions & Future Work:**
  - High-RAP, rejuvenated mixtures are viable for field application, supporting both performance and sustainability goals.
  - Ongoing research will further optimize mix design variables and evaluate long-term field performance.

2025 –Effectiveness of Recycling Agents in High RAP Plant Produced Asphalt Mixtures

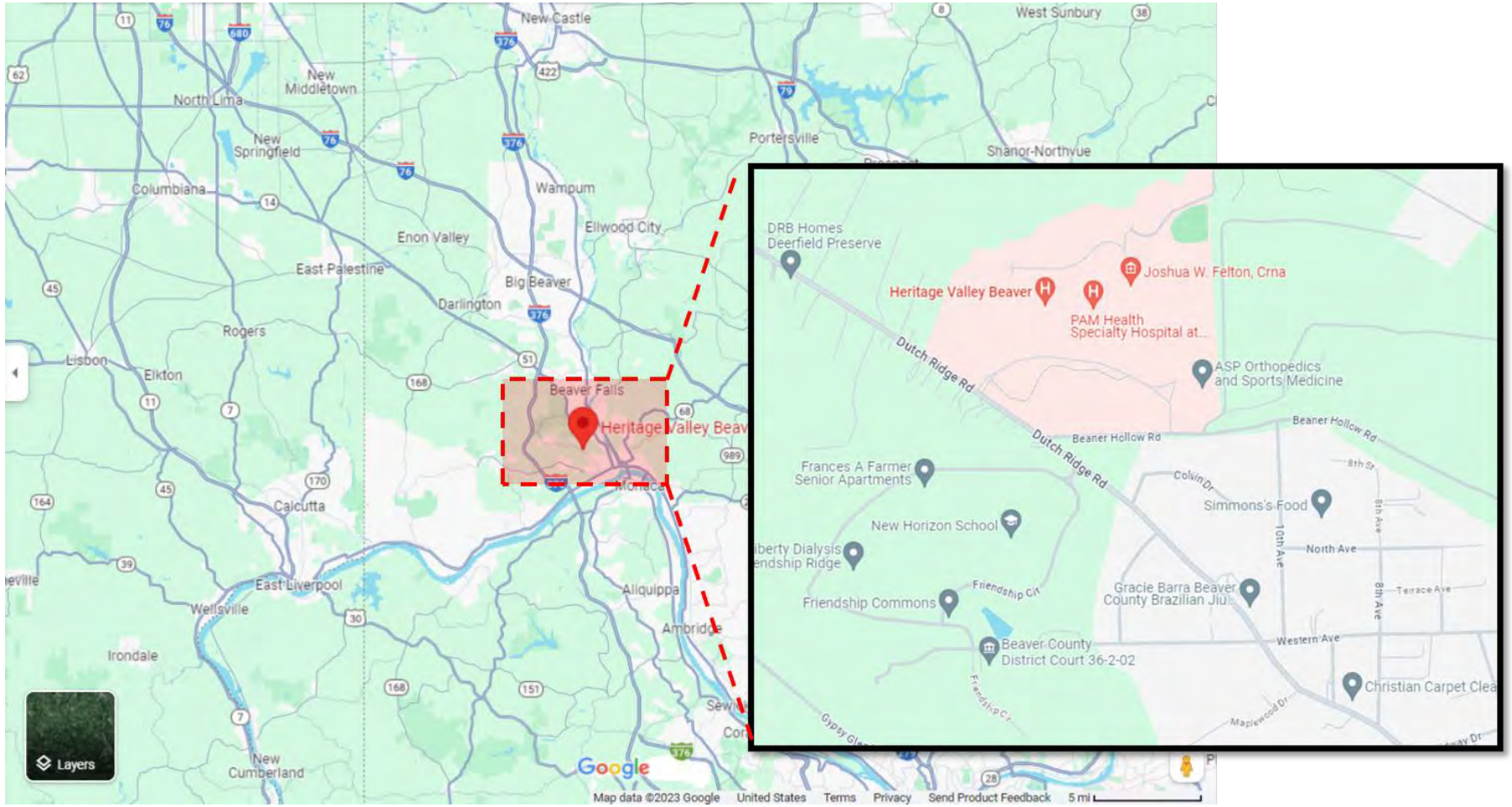
- **Objective**: Evaluate the performance of recycling agents (RA) in asphalt mixtures with high reclaimed asphalt pavement (RAP) content, comparing lab- and plant-produced mixes.
- **Field Pilot: C**ontrol mix from Koppel plant (15% RAP, no RA) vs. two rejuvenated mixes from Neville Island plant (35% RAP, RA types: Cargill-Anova & Ingevity-Evoflex, both at 1.3% dosage).
- **Project Location**: Dutch Ridge Road, Beaver County, PA; 1.5-inch milling and placement of 9.5mm surface course with SRL "H" PG 64S-22 binder..
- **Performance:** After one year, all mixes showed excellent service with acceptable rutting and cracking performance.
  - **Laboratory tests (Hamburg Wheel Track Test, IDEAL-CT)** confirmed mix durability; field cores showed higher rutting, but better cracking resistance compared to lab-compacted samples.
- **Conclusion:** High RAP mixes with rejuvenators can deliver strong field and lab performance, supporting sustainable pavement practices

ingevity

Plant and Project Location



Project Location

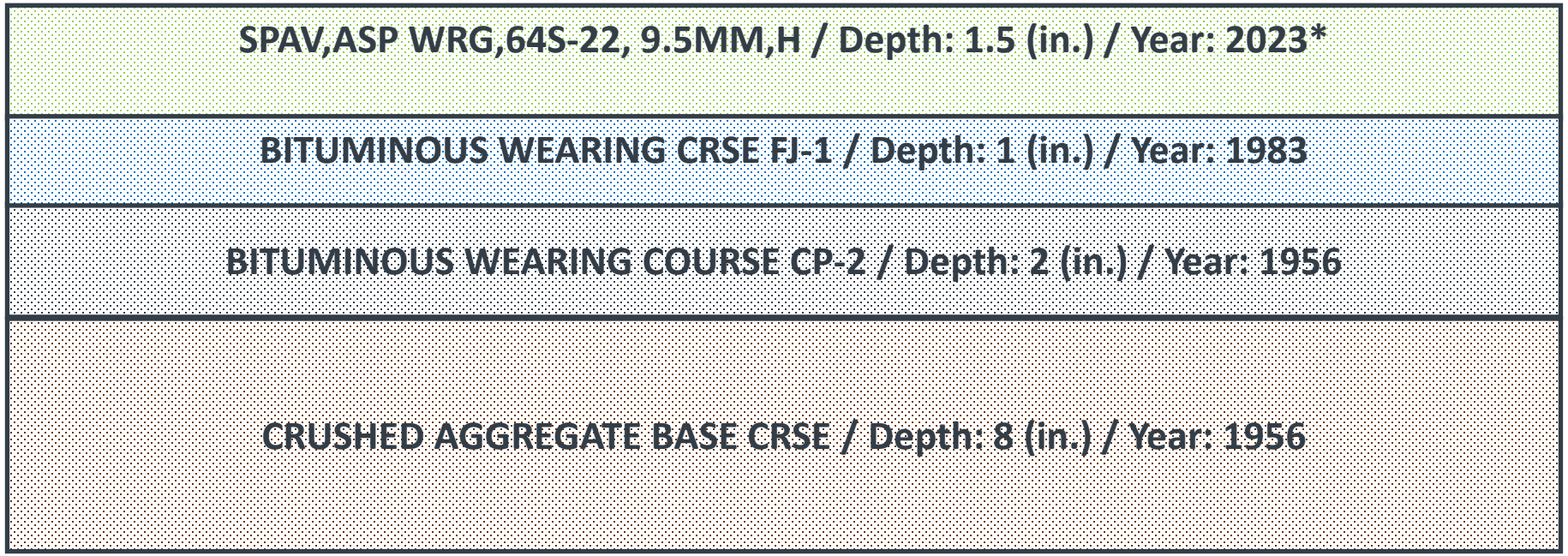


ingevity

Project Location

Pavement Structure

County: Beaver (04) Route: 4018 Segment: 0020 to 0060



*Note: 1.5-inch milling was performed before placing the mixes.

Field Pilot - Mix Design

	Non-Rejuvenated EPD Mix W95121E04	Rejuvenated Mix #1 EPD Mix W95122H22	Rejuvenated Mix #2 EPD Mix W95122H26
Plant	Koppel	Neville Island (NI)	Neville Island (NI)
Final Binder PG	PG64S-22	PG64S-22	PG64S-22
SRL	E	H	H
N_{Design}	50	50	50
NMAS (mm)	9.5	9.5	9.5
RA Type	**NA**	**Cargill- Anova**	**Ingevity- Evoflex**
RA Dosage(%)	**NA**	**1.3**	**1.3**
RAP%	**15**	**35**	**35**
Virgin AC (%)	4.9	3.9	3.9
Total AC (%)	5.7	5.8	5.8
P200 (%)	4.9	6.3	6.3
#8 (%)	48	42	42
#4 (%)	66	60	60

EPDs

Emerald ECO LABEL

An Environmental Product Declaration (EPD) for Asphalt Mixtures

Company Information

Lindy Paving Inc is an asphalt mixture producer.

Koppel, a stationary asphalt plant at

1811 Shenango Road, New Galilee, PA 16141

LINDY PAVING

Product Description

This EPD reports the potential environmental impacts and additional environmental information for an asphalt mixture, which falls under the United Nations Standard Products and Services Code 30111509. Asphalt mixtures are typically incorporated as part of the structure of a roadway, parking lot, driveway, airfield, bike lane, pedestrian path, railroad track bed, or recreational surface.

Mix Name: W95121E04

Specification Entity: PennDOT

Specification: 21A15AE

Gradation Type: dense

Mix Design Method: superpave

Nominal Maximum Aggregate Size: 9.5 mm

Performance Grade of Asphalt Binder: PG 64-22

Customer [Project/Contract] Number: Not Reported

This mix producer categorizes this product as a Warm Mix Asphalt (WMA) asphalt mixture produced using chemical additive. This asphalt mixture was produced within a temperature range of 132 to 160°C (270.0 to 320.0°F) f. Energy and environmental impacts are based on a plant's average performance over a 12-month period and are not adjusted for mix-specific production temperatures.

Environmental Product Declaration NAPA VERIFIED

This declaration is an EPD in accordance with ISO 14025:2006[1] and ISO 21930:2017[2]. The PCR is *Product Category Rules for Asphalt Mixtures*[3,4]. This EPD transparently describes the potential environmental impacts associated with the identified life cycle stages of the described product.

Declaration Number: 101.426.3392 v6 **Software Version:** 2.3.0

Date of Issue: Feb. 11, 2025 **Period of Validity:** March 31, 2027

This EPD is valid for asphalt mixtures produced at the location indicated on this page. Data used to inform this EPD reflect plant operations from a 12-month period beginning on Jan. 1, 2024.

This EPD can be found at https://asphaltepd.org/epd/d/LDUmlv/

LCA performed by: Ben Ciavola, PhD

Emerald ECO LABEL

An Environmental Product Declaration (EPD) for Asphalt Mixtures

Company Information

Lindy Paving Inc is an asphalt mixture producer.

Neville Island, a stationary asphalt plant at

4200 Neville Rd., Pittsburgh, PA 15225

LINDY PAVING

Product Description

This EPD reports the potential environmental impacts and additional environmental information for an asphalt mixture, which falls under the United Nations Standard Products and Services Code 30111509. Asphalt mixtures are typically incorporated as part of the structure of a roadway, parking lot, driveway, airfield, bike lane, pedestrian path, railroad track bed, or recreational surface.

Mix Name: W95122H22

Specification Entity: PennDOT

Specification: 20A35AH

Gradation Type: dense

Mix Design Method: superpave

Nominal Maximum Aggregate Size: 9.5 mm

Performance Grade of Asphalt Binder: PG 64-22

Customer [Project/Contract] Number: Not Reported

This mix producer categorizes this product as a Warm Mix Asphalt (WMA) asphalt mixture produced using chemical additive. This asphalt mixture was produced within a temperature range of 132 to 160°C (270.0 to 320.0°F) f. Energy and environmental impacts are based on a plant's average performance over a 12-month period and are not adjusted for mix-specific production temperatures.

Environmental Product Declaration NAPA VERIFIED

This declaration is an EPD in accordance with ISO 14025:2006[1] and ISO 21930:2017[2]. The PCR is *Product Category Rules for Asphalt Mixtures*[3,4]. This EPD transparently describes the potential environmental impacts associated with the identified life cycle stages of the described product.

Declaration Number: 101.254.3238 v4 **Software Version:** 2.3.0

Date of Issue: Jan. 30, 2025 **Period of Validity:** March 31, 2027

This EPD is valid for asphalt mixtures produced at the location indicated on this page. Data used to inform this EPD reflect plant operations from a 12-month period beginning on Jan. 1, 2024.

This EPD can be found at https://asphaltepd.org/epd/d/25UJQL/

LCA performed by: Ben Ciavola, PhD

Emerald ECO LABEL

An Environmental Product Declaration (EPD) for Asphalt Mixtures

Company Information

Lindy Paving Inc is an asphalt mixture producer.

Neville Island, a stationary asphalt plant at

4200 Neville Rd., Pittsburgh, PA 15225

LINDY PAVING

Product Description

This EPD reports the potential environmental impacts and additional environmental information for an asphalt mixture, which falls under the United Nations Standard Products and Services Code 30111509. Asphalt mixtures are typically incorporated as part of the structure of a roadway, parking lot, driveway, airfield, bike lane, pedestrian path, railroad track bed, or recreational surface.

Mix Name: W95122H26

Specification Entity: PennDOT

Specification: 20A35AH

Gradation Type: dense

Mix Design Method: superpave

Nominal Maximum Aggregate Size: 9.5 mm

Performance Grade of Asphalt Binder: PG 64-22

Customer [Project/Contract] Number: Not Reported

This mix producer categorizes this product as a Warm Mix Asphalt (WMA) asphalt mixture produced using chemical additive. This asphalt mixture was produced within a temperature range of 132 to 160°C (270.0 to 320.0°F) f. Energy and environmental impacts are based on a plant's average performance over a 12-month period and are not adjusted for mix-specific production temperatures.

Environmental Product Declaration NAPA VERIFIED

This declaration is an EPD in accordance with ISO 14025:2006[1] and ISO 21930:2017[2]. The PCR is *Product Category Rules for Asphalt Mixtures*[3,4]. This EPD transparently describes the potential environmental impacts associated with the identified life cycle stages of the described product.

Declaration Number: 101.254.10829 v1 **Software Version:** 2.3.1

Date of Issue: Oct. 31, 2025 **Period of Validity:** March 31, 2027

This EPD is valid for asphalt mixtures produced at the location indicated on this page. Data used to inform this EPD reflect plant operations from a 12-month period beginning on Jan. 1, 2024.

This EPD can be found at https://asphaltepd.org/epd/d/yeU64q/

LCA performed by: Ben Ciavola, PhD

ingevity

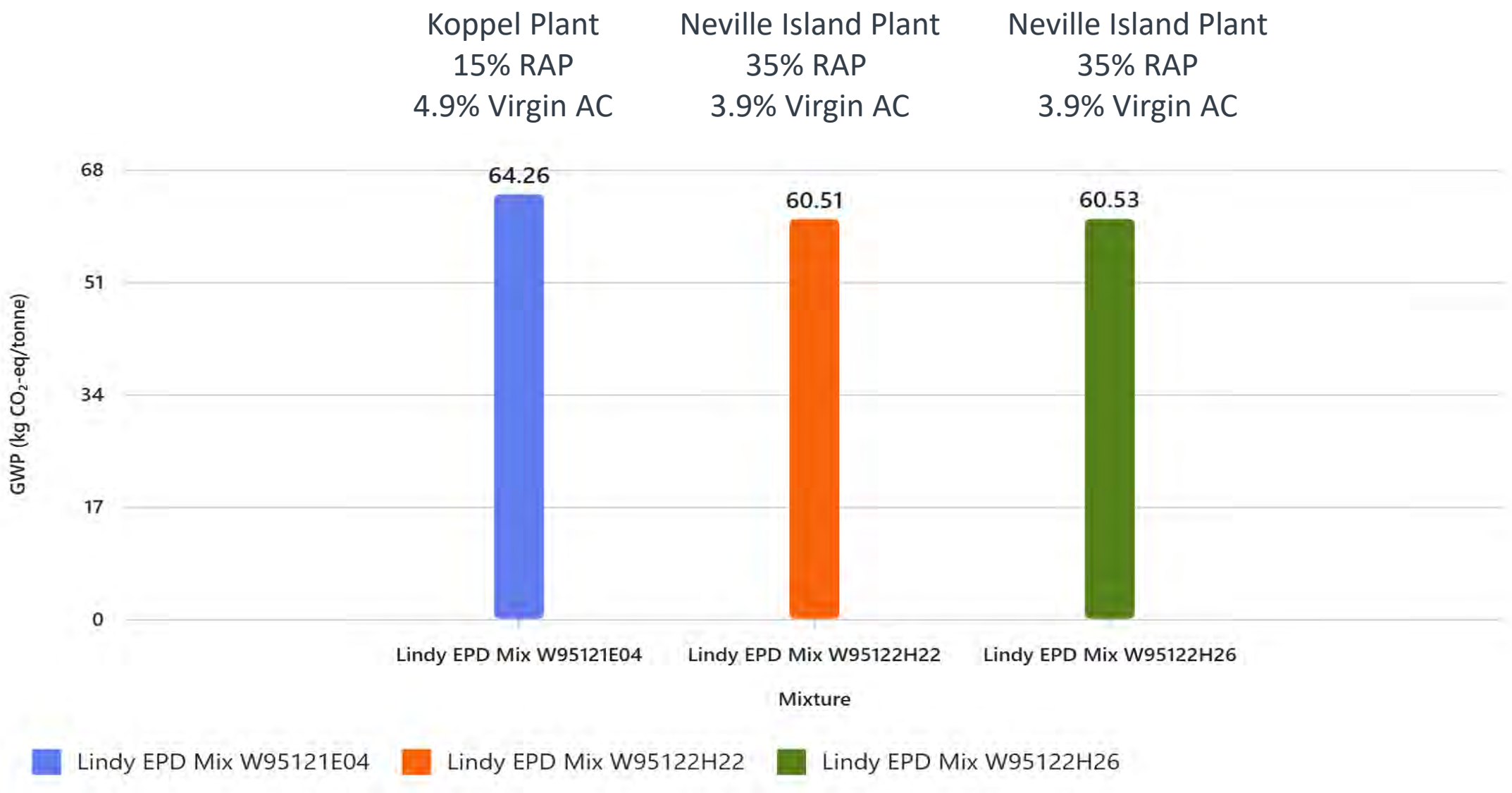
Mixture EPDs

Attribute	Lindy EPD Mix W95121E04	Lindy EPD Mix W95122H22	Lindy EPD Mix W95122H26
Plant Location	Koppel	Neville Island	Neville Island
Mix Name	W95121E04	W95122H22	W95122H26
PennDOT Spec	21A15AE	20A35AH	20A35AH
Gradation Type	Dense	Dense	Dense
Mix Design Method	Superpave	Superpave	Superpave
Nominal Max. Aggregate Size	9.5 mm	9.5 mm	9.5 mm
Binder Grade	PG 64-22	PG 64-22	PG 64-22
RAP Content	15%	35%	35%
Binder Additive	Ingevity Evotherm M1	Warm Mix Additive - Chemical	Ingevity Evotherm M1
Aggregate (Natural Stone)	42%, 38%	9%, 20%, 16%, 16%	9%, 20%, 16%, 16%
Binder (Unmodified)	5%	4%	4%

Mixture EPDs

Attribute	Lindy EPD Mix W95121E04	Lindy EPD Mix W95122H22	Lindy EPD Mix W95122H26
Global Warming Potential (kg CO_2-eq/tonne)	64.26	60.51	60.53
Ozone Depletion Potential (kg CFC-11-eq/tonne)	1.06e-07	8.42e-08	9.77e-08
Eutrophication Potential (kg N-eq/tonne)	1.37e-02	1.35e-02	1.35e-02
Acidification Potential (kg SO_2-eq/tonne)	1.85e-01	1.95e-01	1.96e-01
Photochemical Ozone Creation (kg O_3-eq/tonne)	4.66	5.04	5.04
Secondary (Recycled) Materials (kg/tonne)	150	350	350
Declaration Number	101.426.3392 v6	101.254.3238 v4	101.254.10829 v1
Issue Date	Feb. 11, 2025	Jan. 30, 2025	Oct. 31, 2025
Software Version	2.3.0	2.3.0	2.3.1

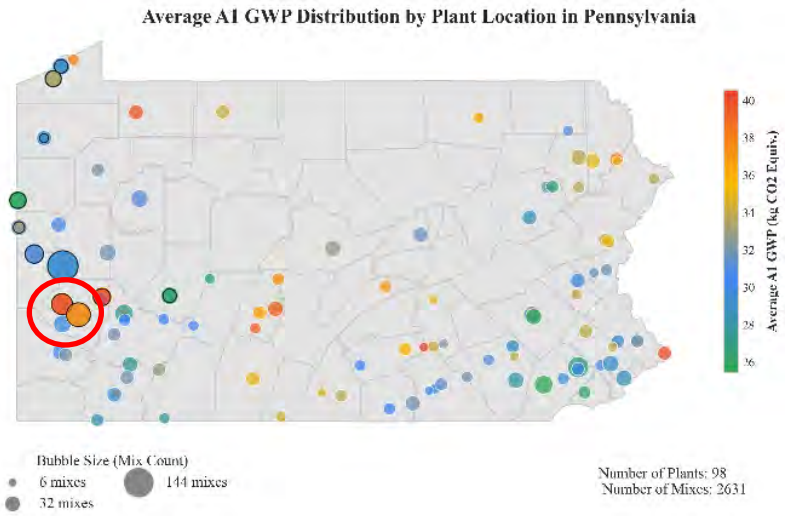
GWP-100 (kg CO_2 eq/tonne)

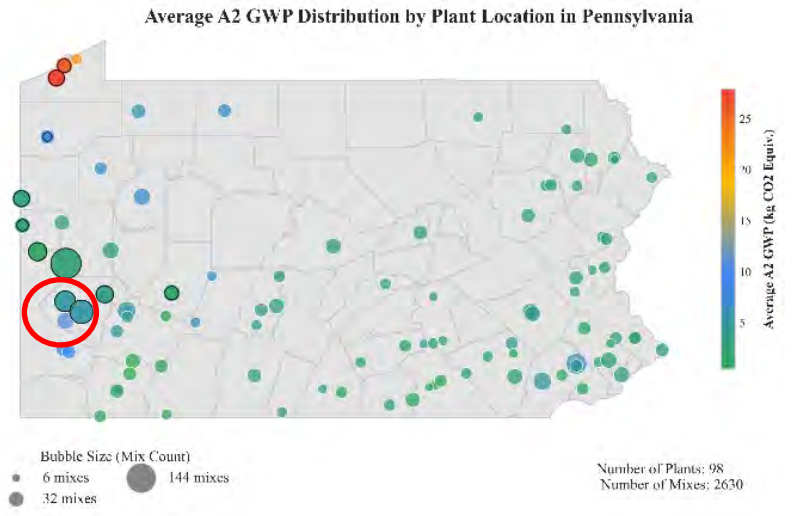


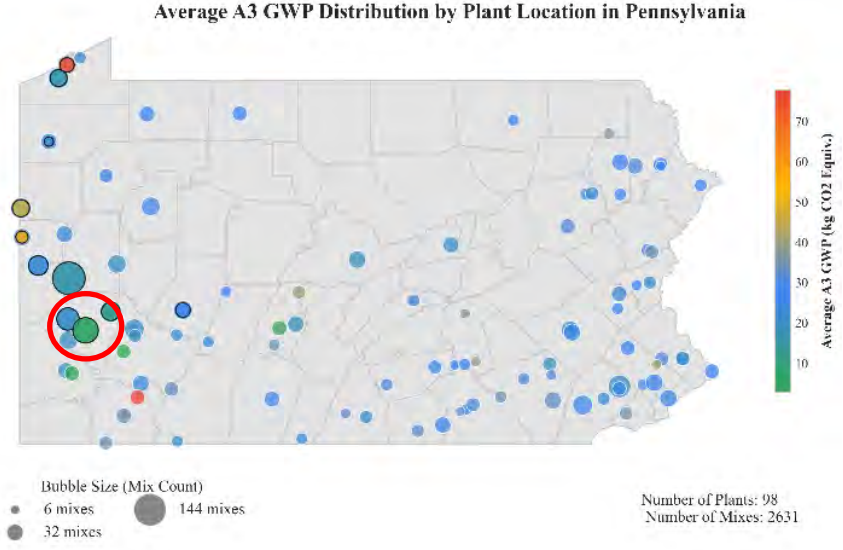
Key Differences

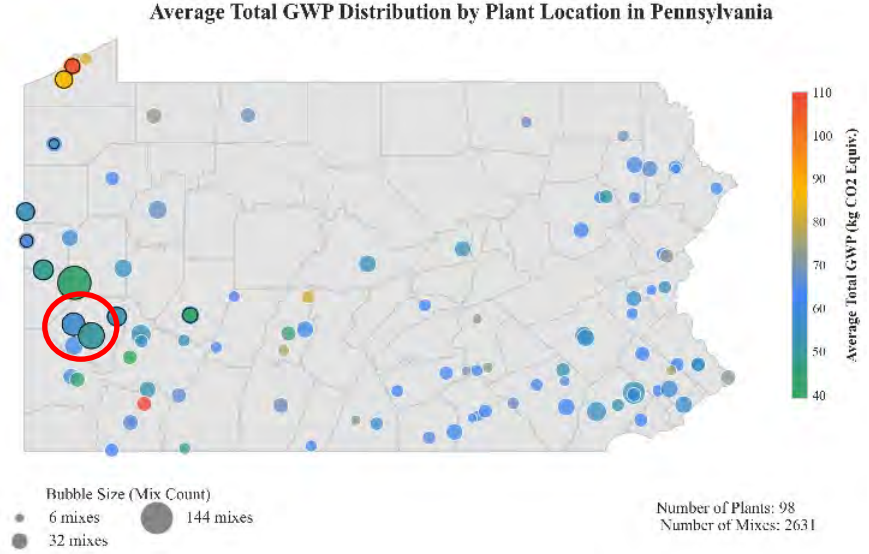
- The main differences are
  - Plant location, RAP content (higher in H22 and H26 mixtures produced at the Neville Island Plant)
  - Minor differences in environmental impact indicators
  - H22 and H26 are nearly identical in composition and impacts, differing only in declaration number and issue date.
  - H22 and H26 used different Rejuvenators
- W95121E04 (Koppel) uses less RAP and has higher binder and aggregate content, resulting in a higher global warming potential and lower recycled content.

GWP Distribution by Plant Location



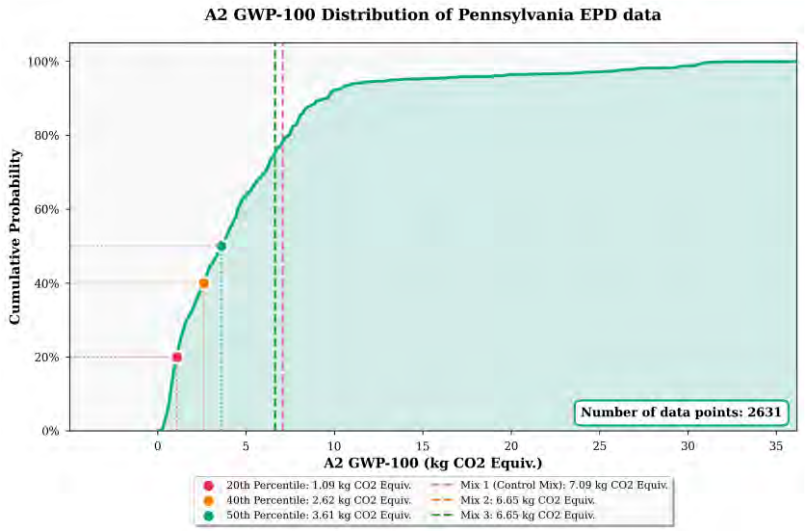


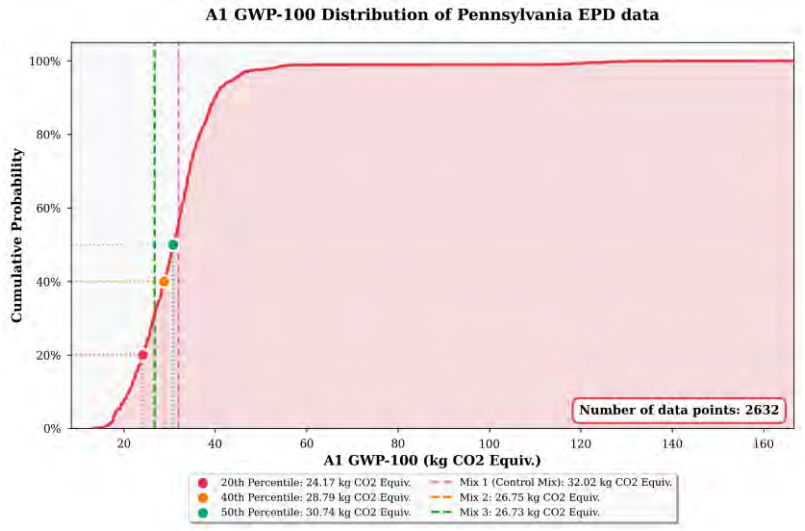


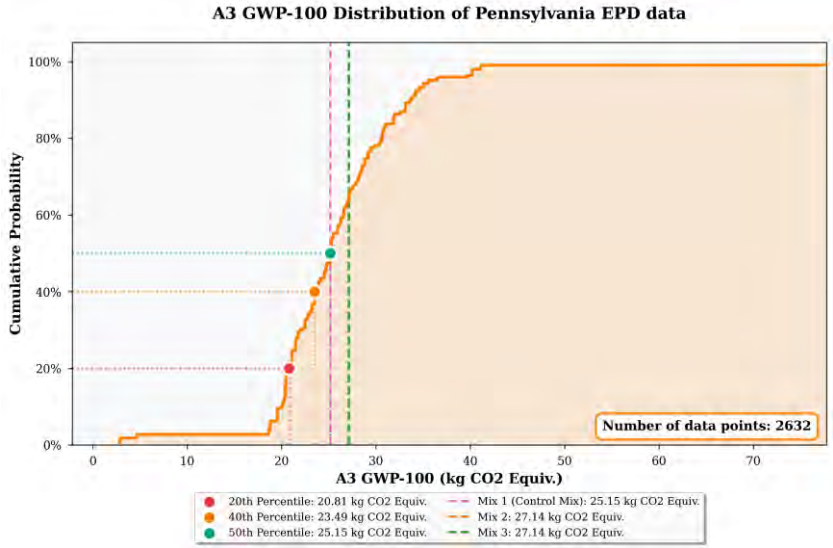


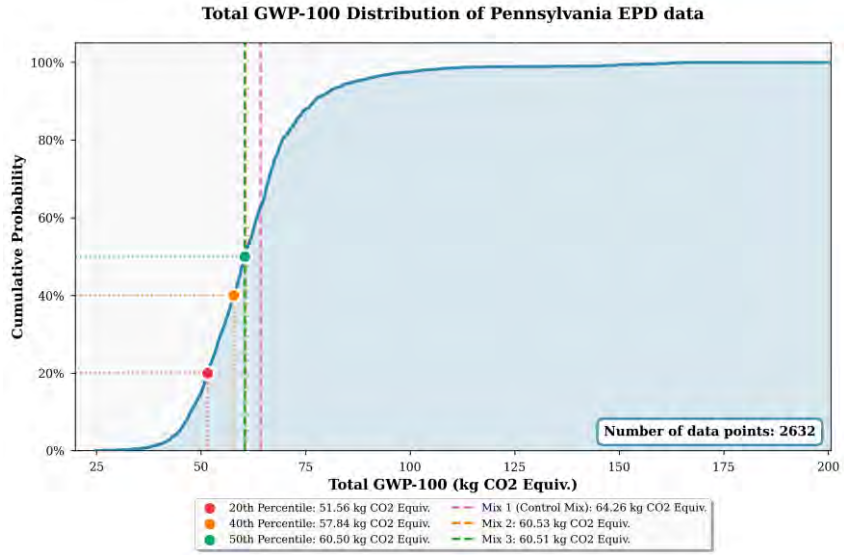
ingevity

GWP-100 CDF Plot All PA

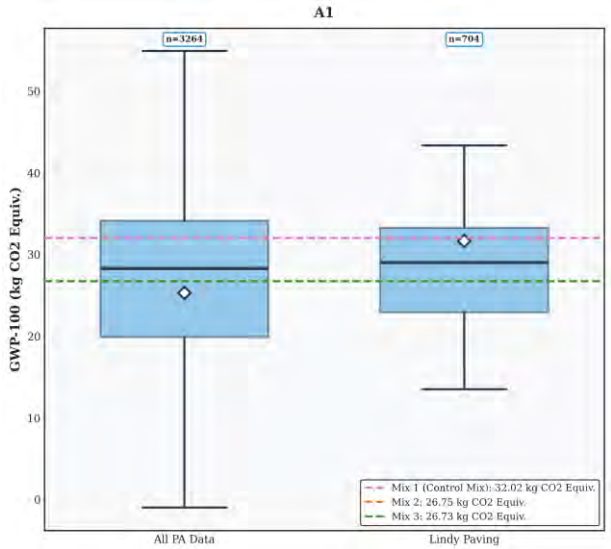


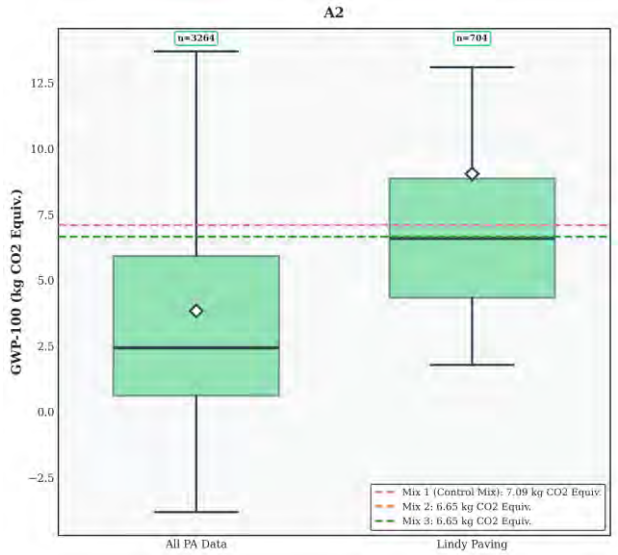


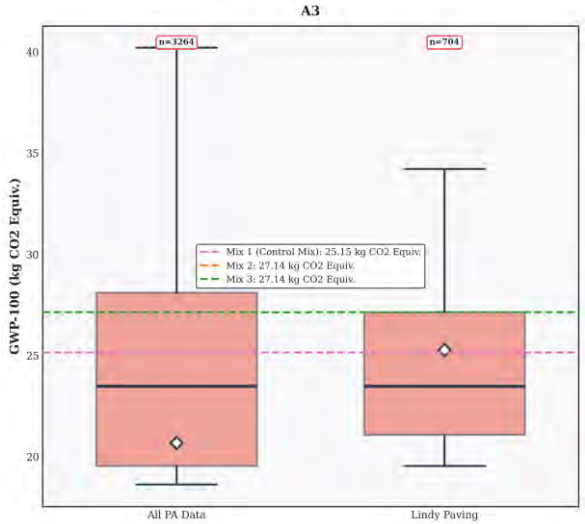


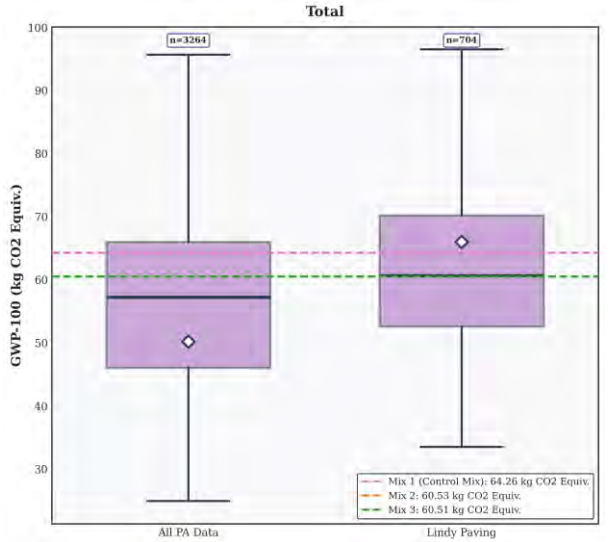


Box Plots

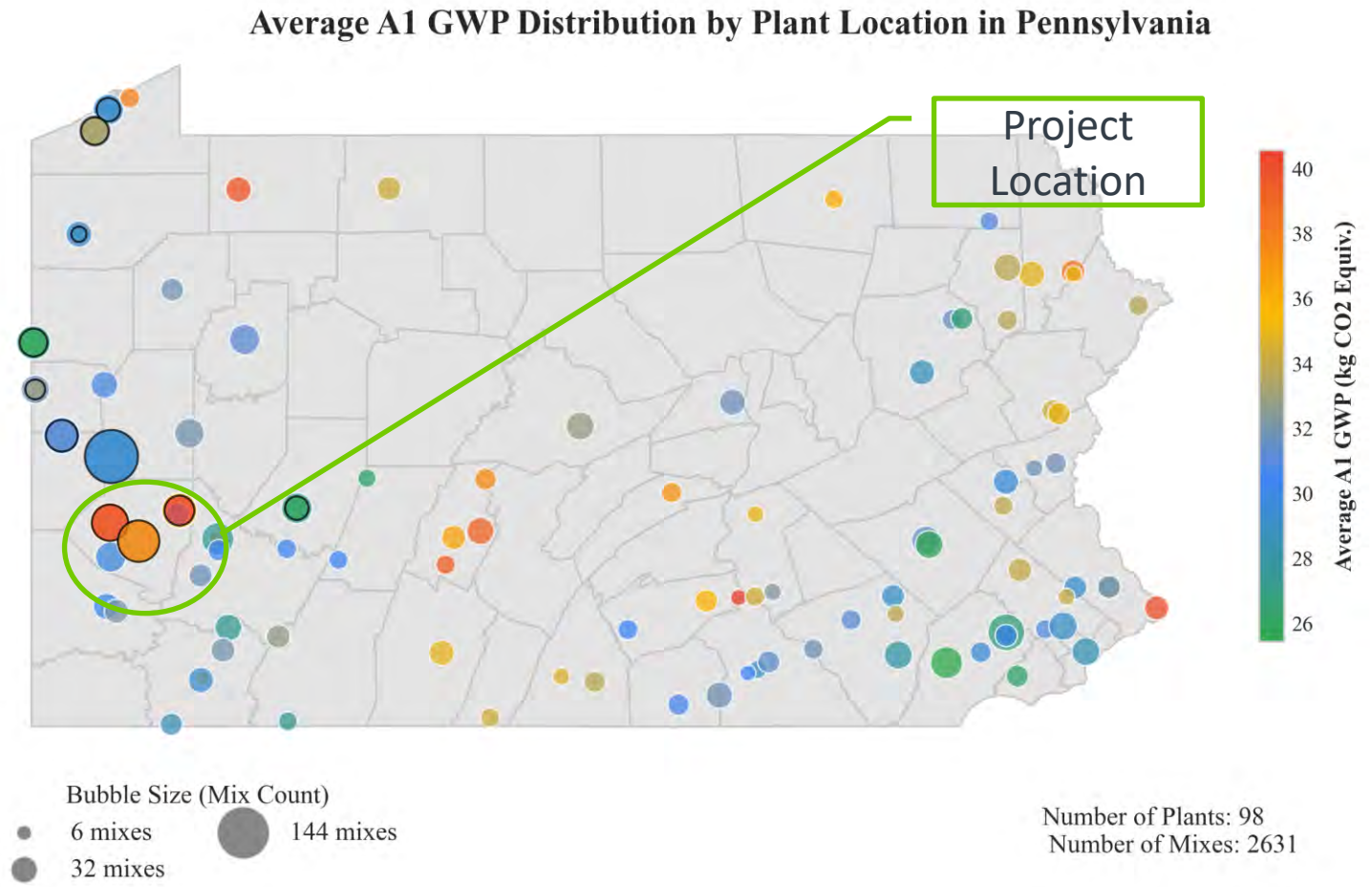

A1
n=3264
n=704
GWP-100 (kg CO2 Equiv.)
Mix 1 (Control Mix): 32.02 kg CO2 Equiv.
Mix 2: 26.75 kg CO2 Equiv.
Mix 3: 26.73 kg CO2 Equiv.
All PA Data
Lindy Paving


A2
n=3264
n=704
GWP-100 (kg CO2 Equiv.)
Mix 1 (Control Mix): 7.09 kg CO2 Equiv.
Mix 2: 6.65 kg CO2 Equiv.
Mix 3: 6.65 kg CO2 Equiv.
All PA Data
Lindy Paving

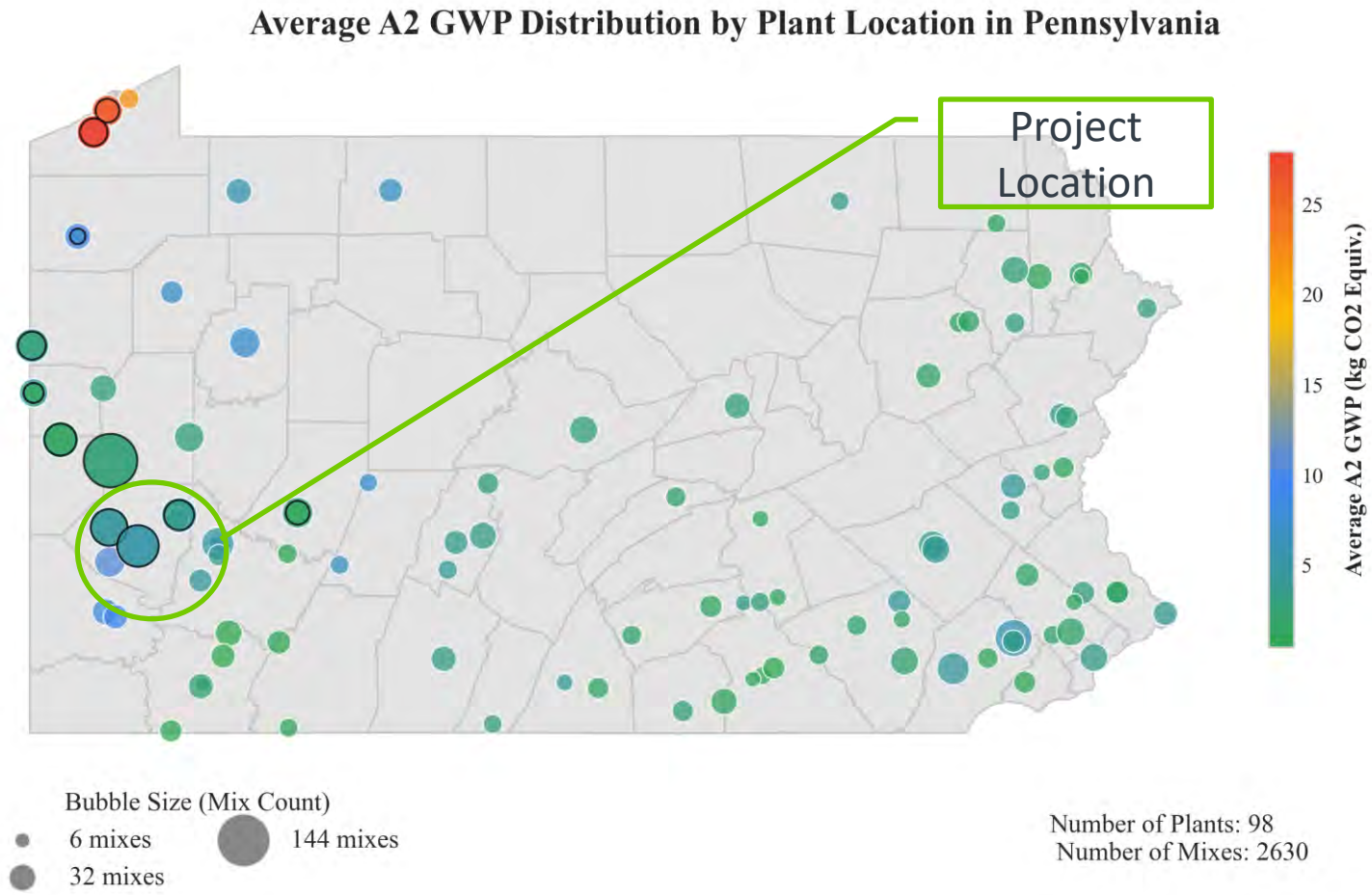

A3
n=3264
n=704
GWP-100 (kg CO2 Equiv.)
Mix 1 (Control Mix): 25.15 kg CO2 Equiv.
Mix 2: 27.14 kg CO2 Equiv.
Mix 3: 27.14 kg CO2 Equiv.
All PA Data
Lindy Paving


Total
n=3264
n=704
GWP-100 (kg CO2 Equiv.)
Mix 1 (Control Mix): 64.26 kg CO2 Equiv.
Mix 2: 60.53 kg CO2 Equiv.
Mix 3: 60.51 kg CO2 Equiv.
All PA Data
Lindy Paving

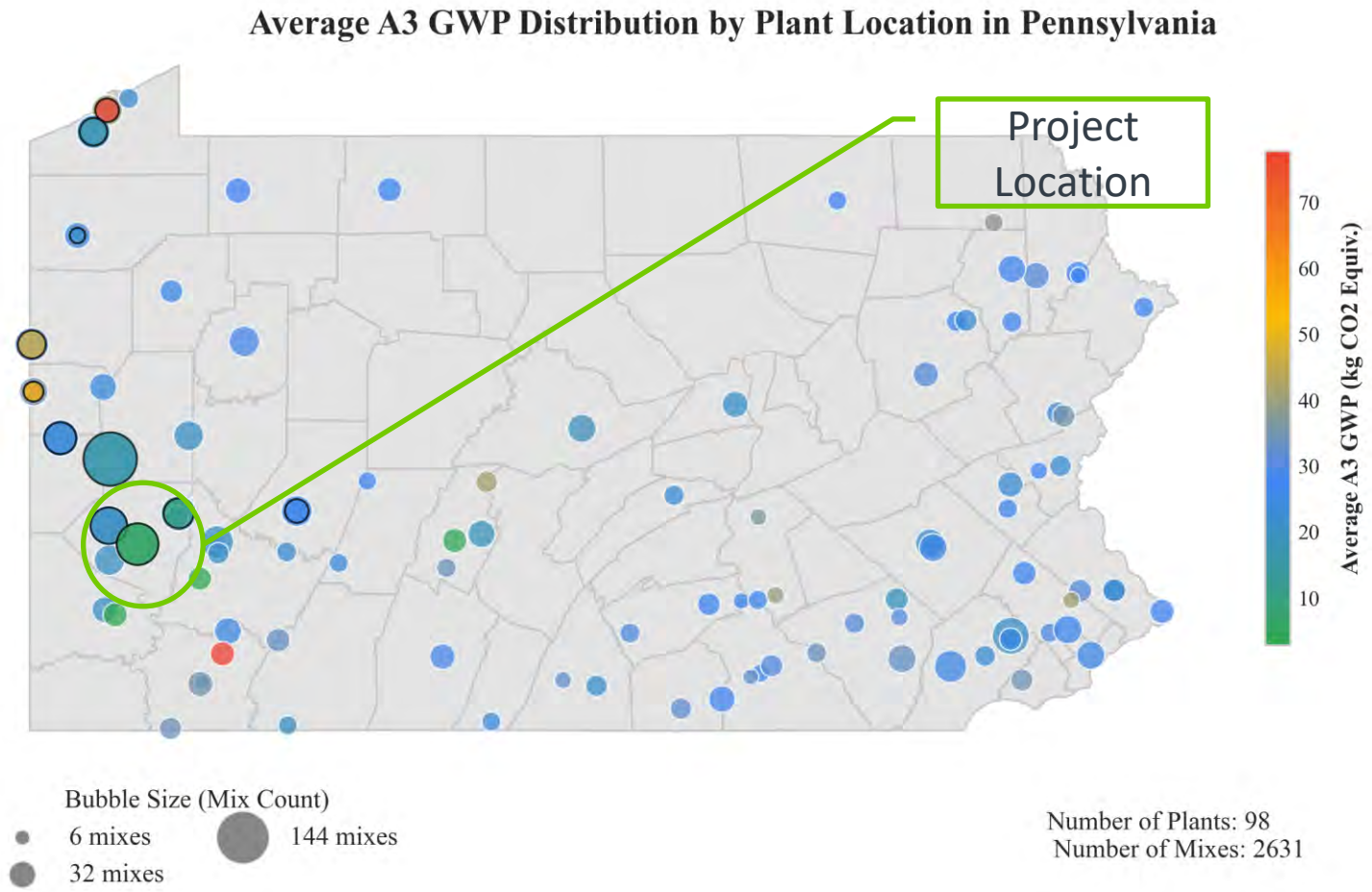
Avg A1 GWP Distribution by Plant Location



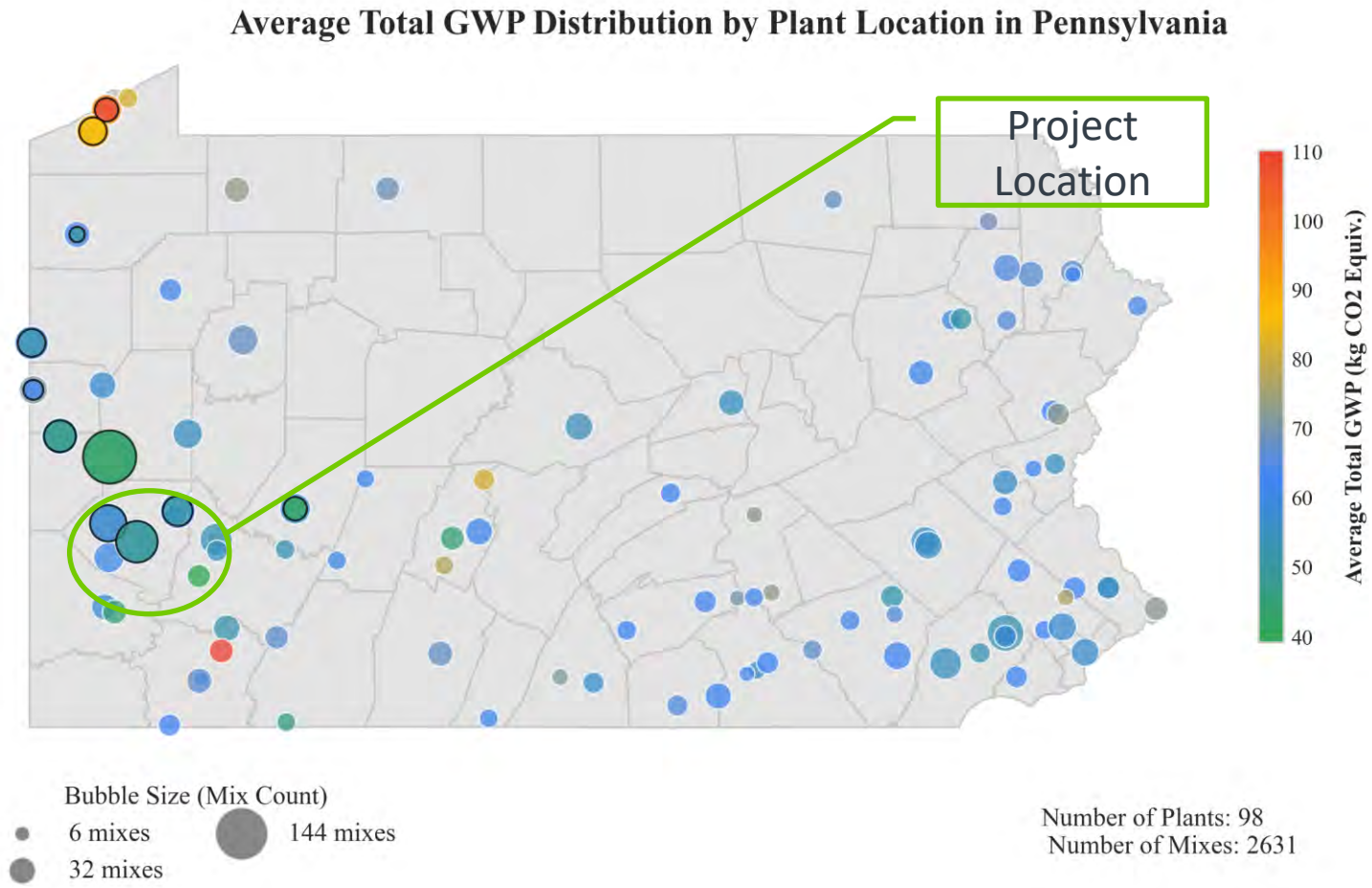
Avg A2 GWP Distribution by Plant Location



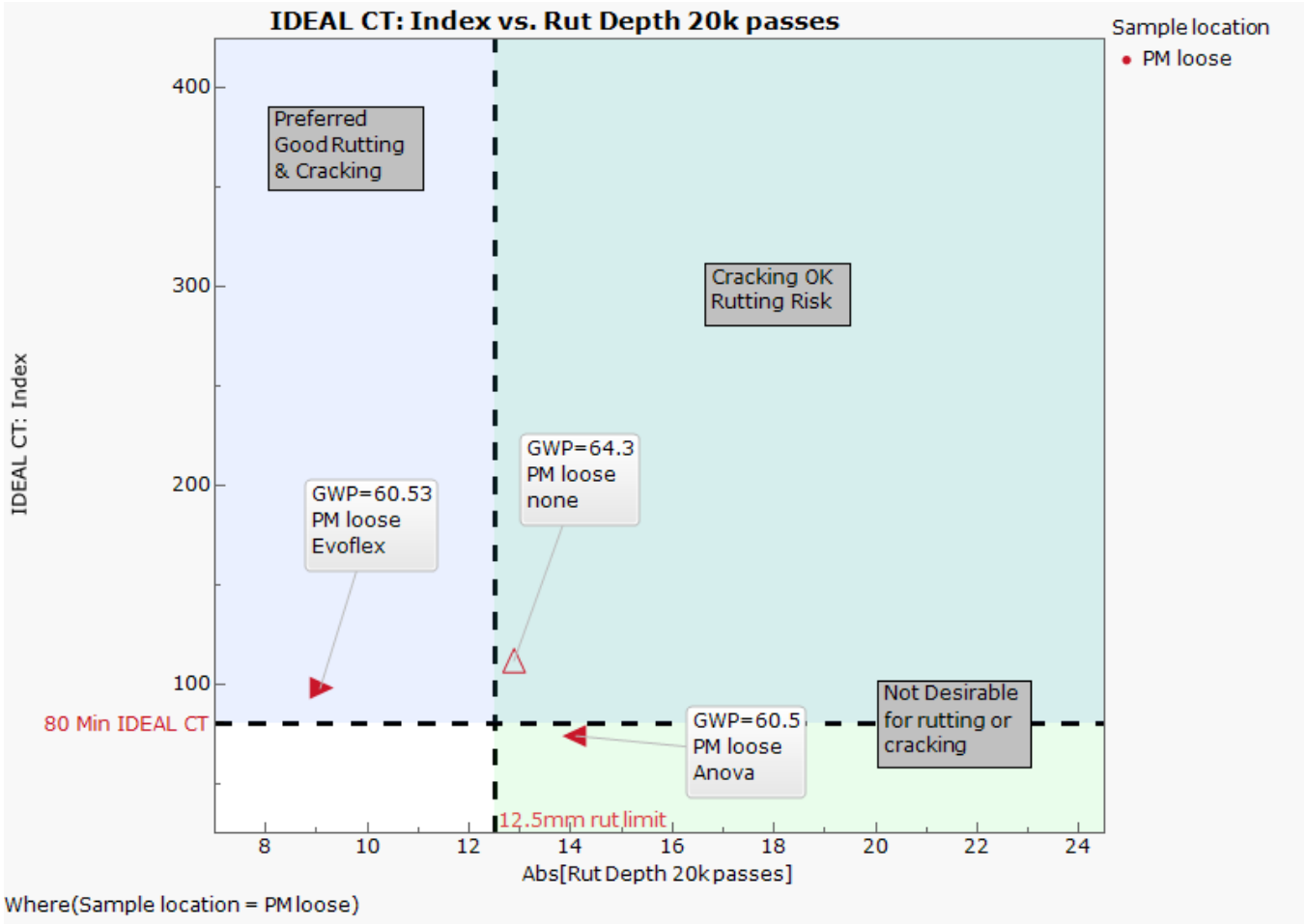
Avg A3 GWP Distribution by Plant Location



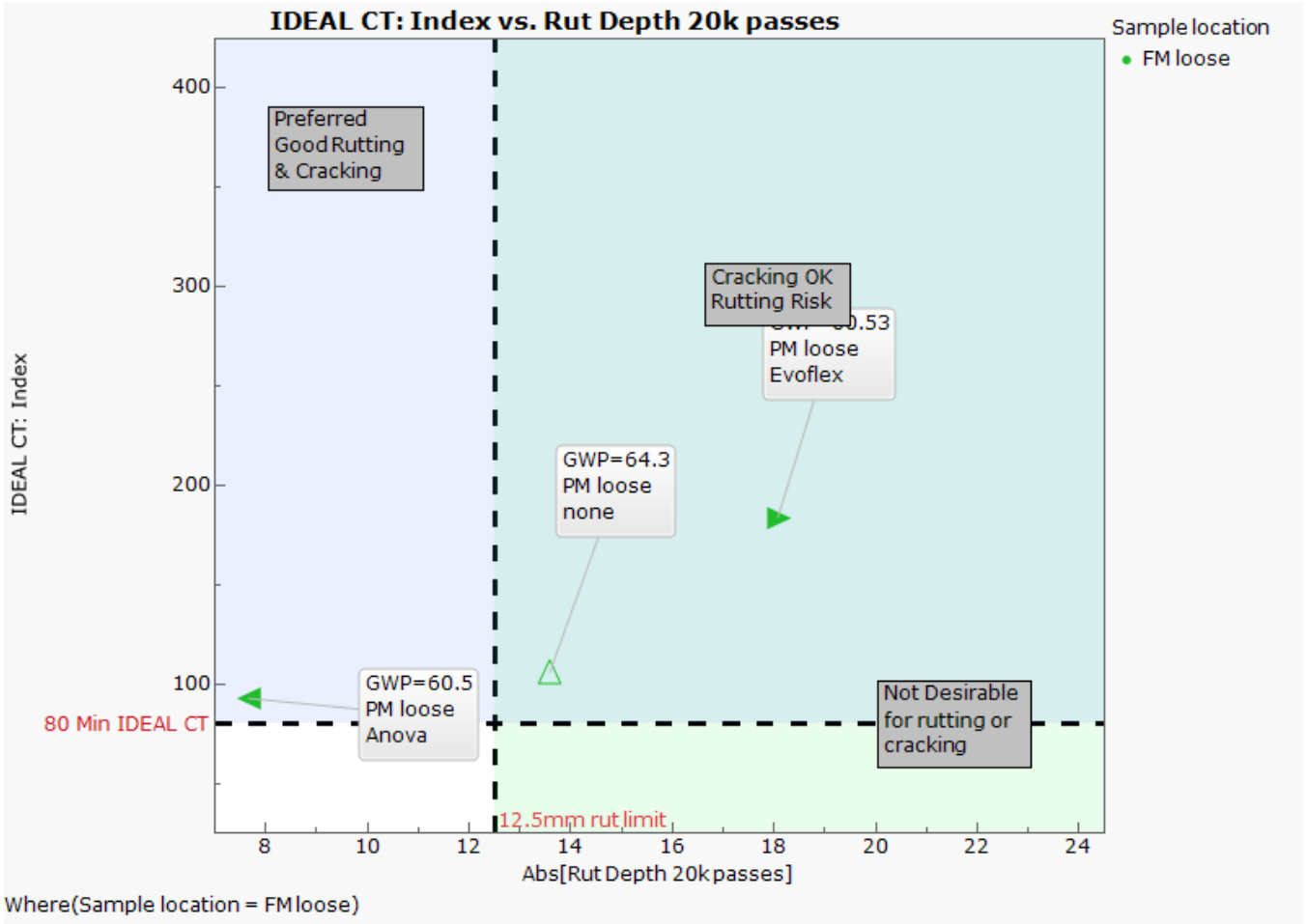
A1-A3 Total GWP Distribution by Plant Location



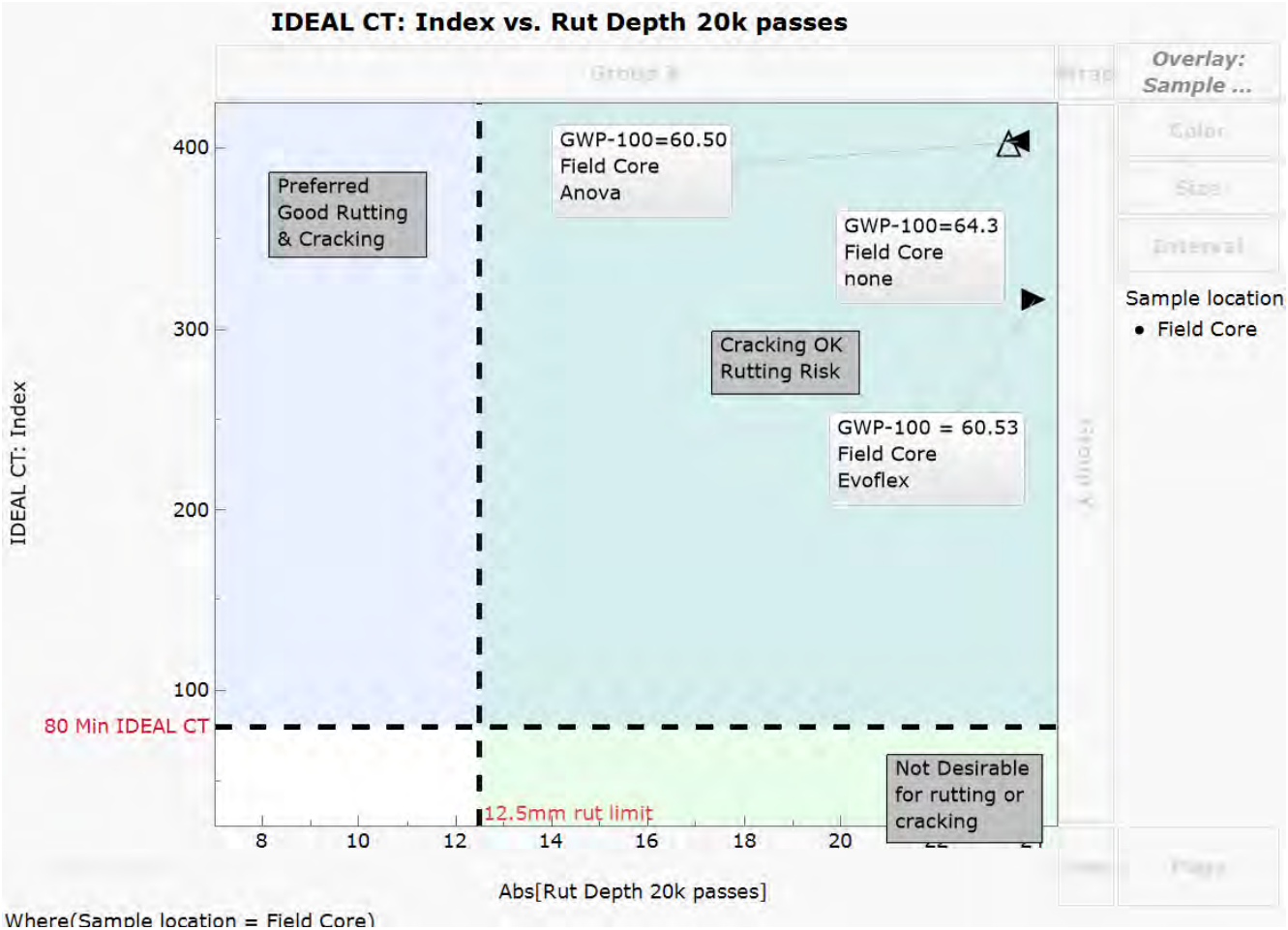
Rejuvenated Mix Performance



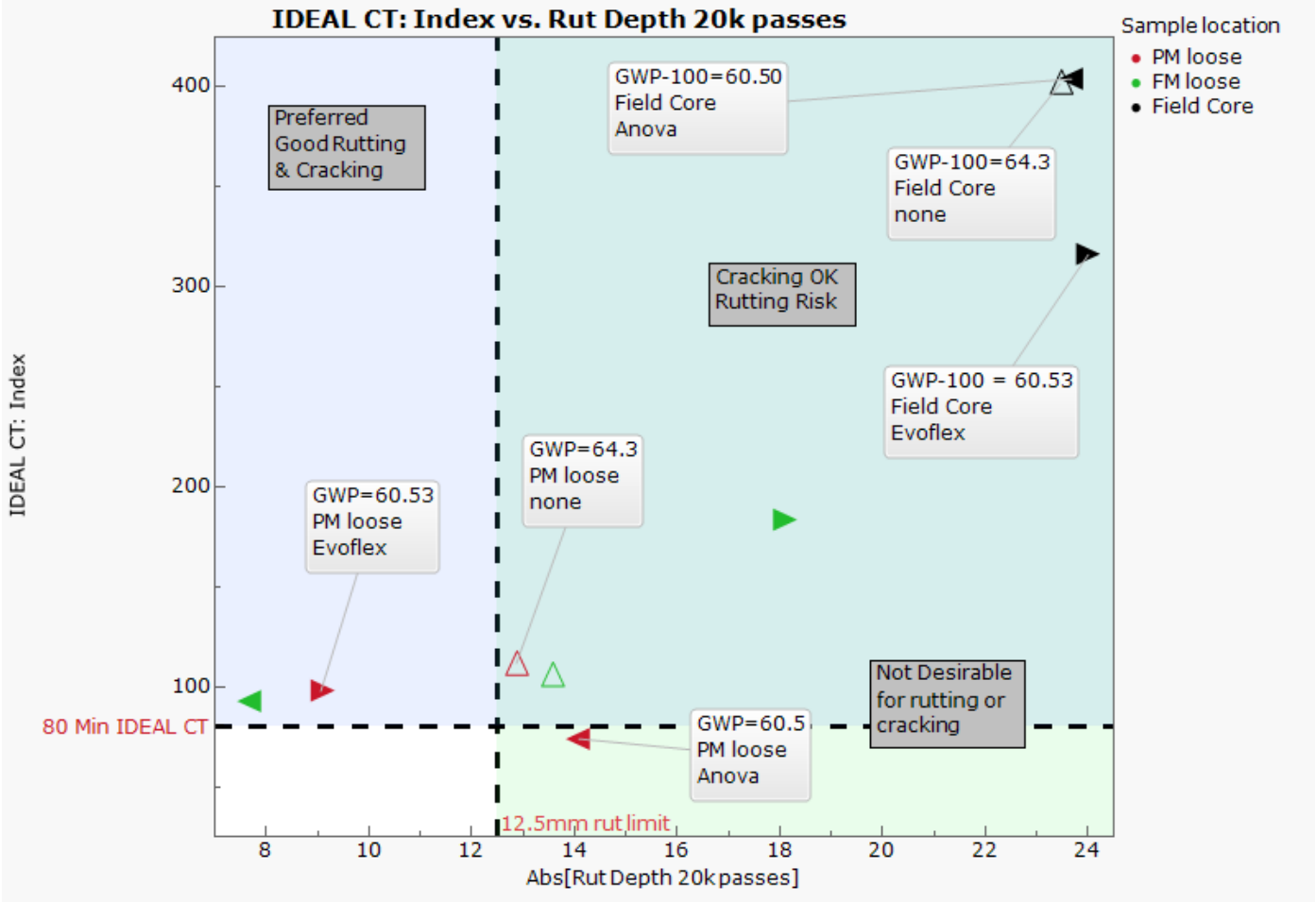
Rejuvenated Mix Performance



Rejuvenated Mix Performance



Rejuvenated Mix Performance



Why Some Mixtures Exceed 12.5 mm Rut Depth

- Hamburg rut depths exceeding 12.5 mm are not desirable and indicate increased rutting susceptibility.
- Elevated rutting values may result from factors independent of rejuvenator use, including:
  - Aggregate structure and coarse aggregate angularity
  - Effective binder content and volumetrics
  - Gradation shape and dust-to-binder ratio
  - Test temperature and moisture conditioning severity
- Rejuvenators are intended to restore aged binder cracking resistance; they do not replace mixture design controls required to manage rutting performance.
- These results reinforce the importance of balanced mixture design when incorporating higher RAP levels

Mix Environmental Performance

- Rejuvenators enable higher RAP content
- Performance-based acceptance is key
- Environmental benefits are measurable
- Field and lab results generally align
- Document and pair criteria for success

Rejuvenators in High RAP Asphalt Mixtures

Performance	Both RA mixes demonstrated rutting resistance and cracking tolerance equal to or better than the control mix RA mixes outperformed the control in cracking
Sustainability	RA mixes achieved lower GWP-100 values compared to the control, supporting the environmental benefits of higher RAP content
Key Insight	Properly dosed RA mixtures enable higher RAP adoption without sacrificing pavement durability or environmental performance
Best Practice	Pairing performance-based acceptance criteria with environmental metrics ensures that sustainability goals are met without compromising durability

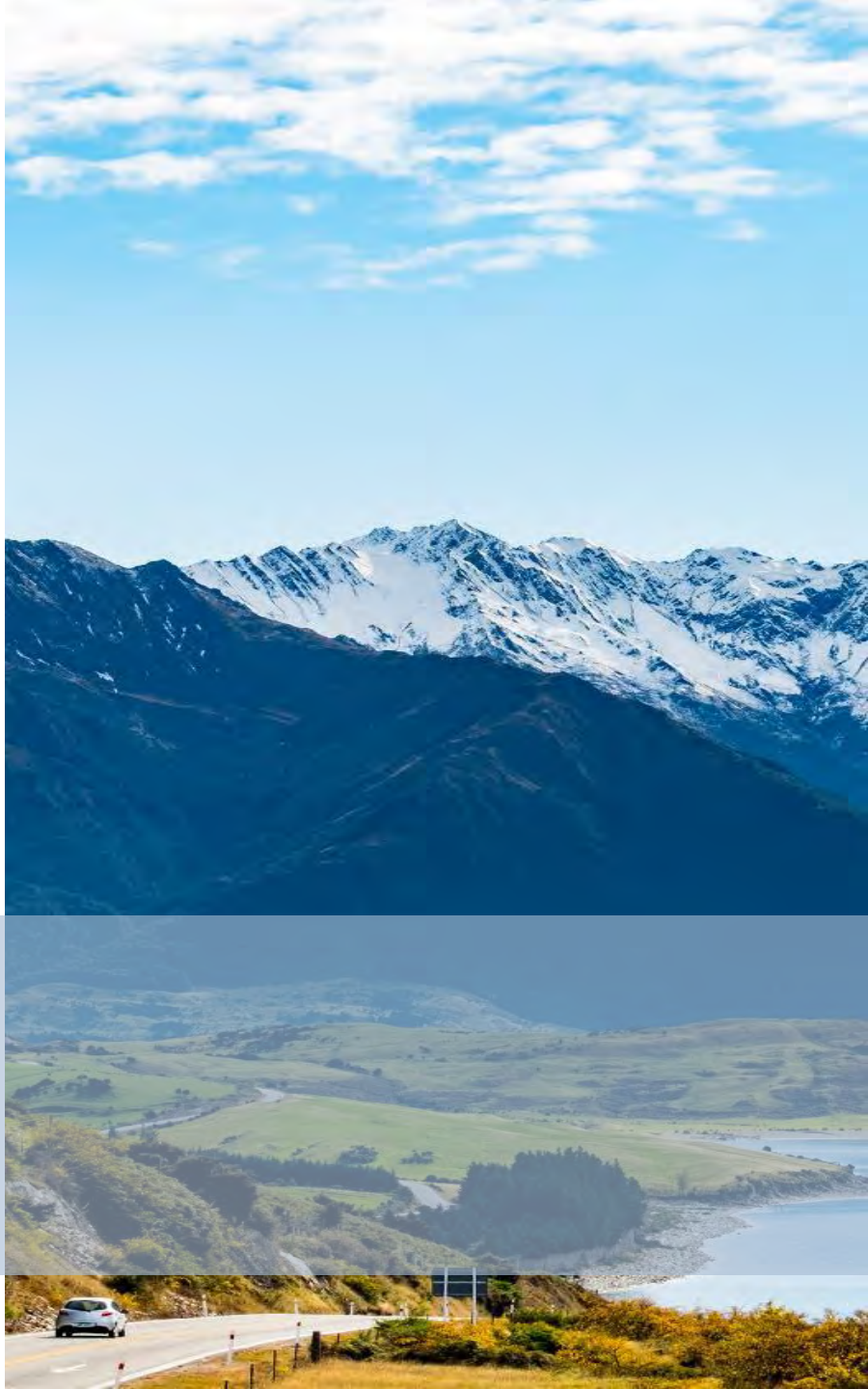
Summary of GWP Impact

Higher RAP %	Showed lower GWP Supports Sustainability Goals
Environmental Indicators	Ozone depletion, eutrophication, acidification, and photochemical ozone creation were similar across all mixtures, with only minor differences
RA Influence	Neville Island mixes using RA performed better than Koppel in GWP
RA Enables Sustainability	Use of RAs allows higher RAP adoption without sacrificing environmental or performance criteria

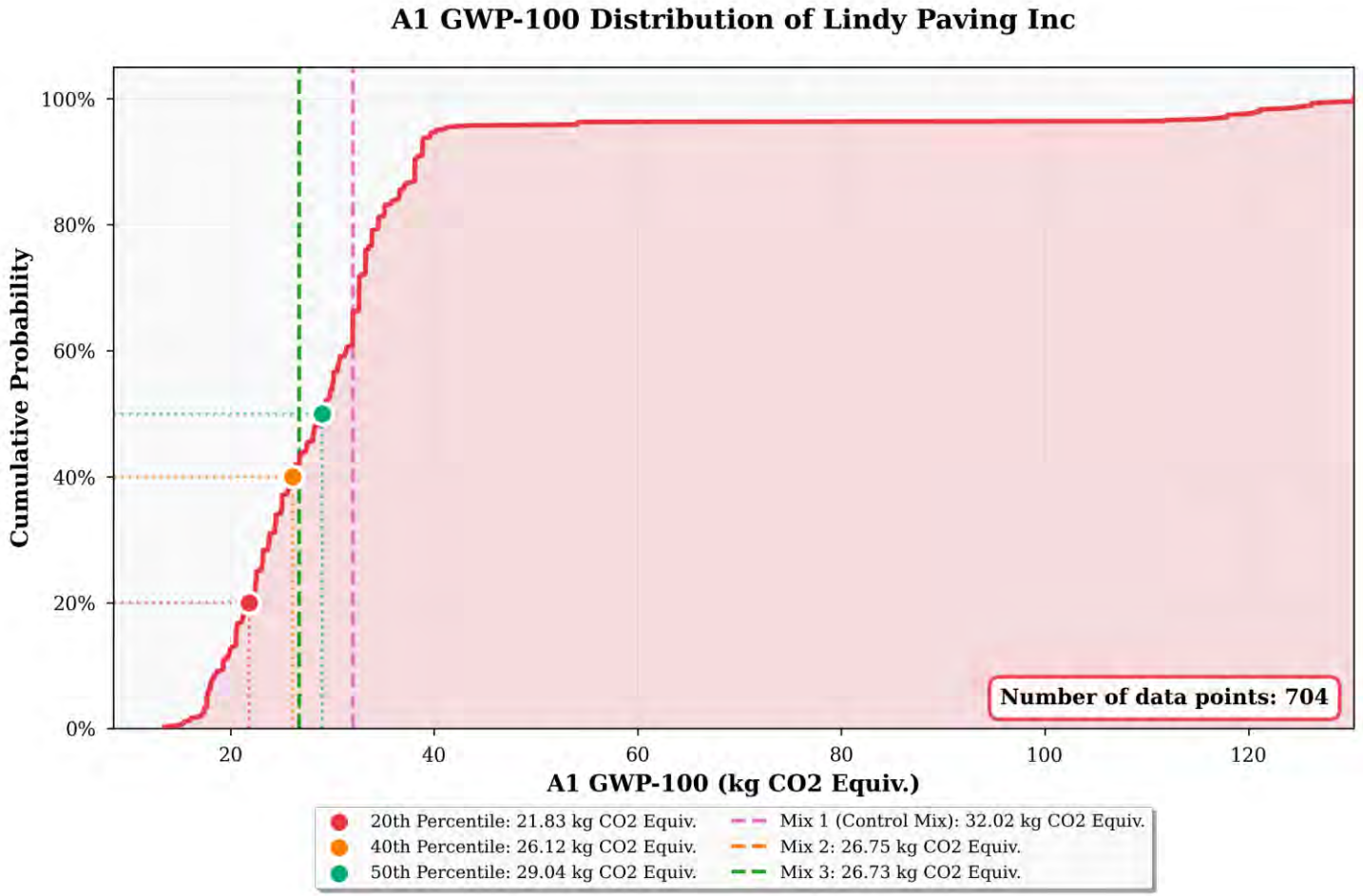
Optional Sensitivity: A4/A5 Implications for PA Projects

- The presentation abstract mentioned inclusion of A4 (transportation to construction site) and A5 (Construction Operations). Since the 35% RPA mixtures were produced in the same plant and the 15% RAP mixture was produced at a plant a similar distance away, the A4 and A5 components are similar for all three mixtures.
  - For typical PennDOT projects, asphalt mixture haul distances commonly range from approximately 20–40 miles.
  - The overall impact on emissions and fuel consumption during the transport stage depends on the balance between reduced virgin material transport and any additional transport required for RAP. If RAP is sourced locally, emissions and fuel consumption can be significantly reduced.
  - Construction-stage impacts (A5) are primarily driven by fuel use and placement operations. Workability can be impacted; however, WMA and RA technology can reduce or eliminate issues of workability.
  - When combined with documented A1–A3 reductions, inclusion of A4 and A5 would be expected to further favor higher-RAP mixtures that meet performance criteria.

Richard Steger
Ingevity
richardsteger@ingevity.com

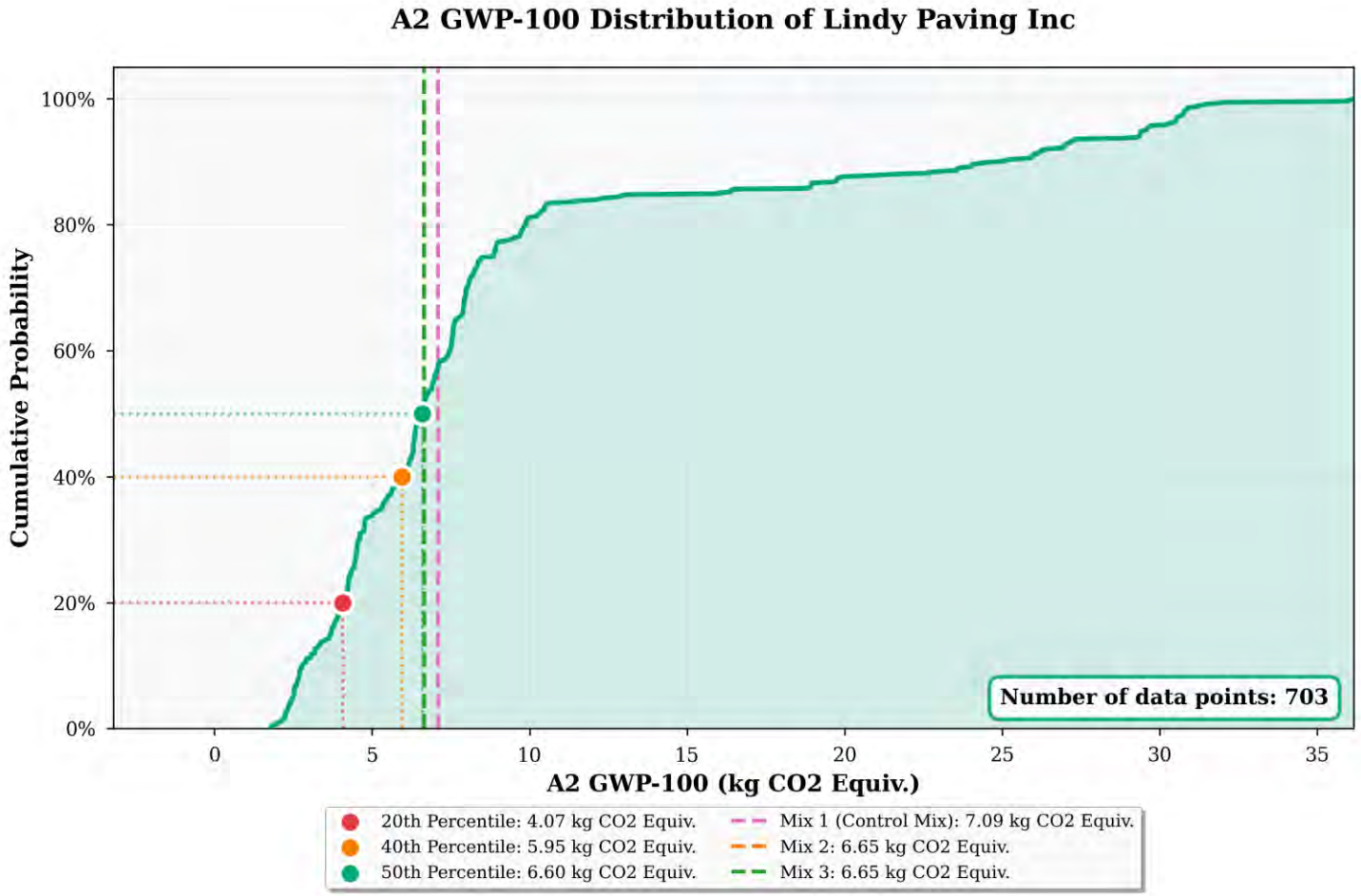


A1 GWP CDF for Lindy Paving Mixtures



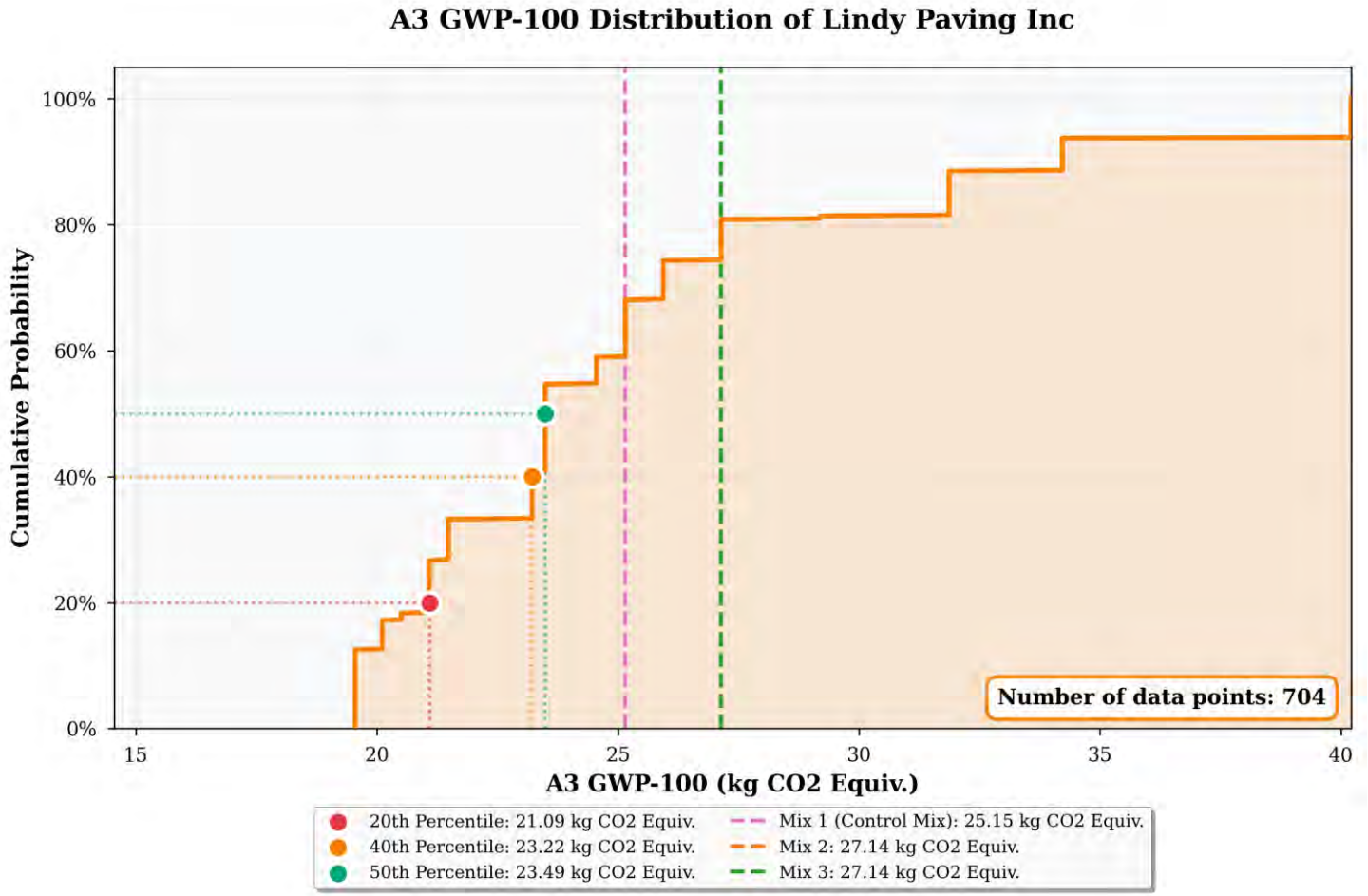
ingevity

A2 GWP-100 for Lindy Paving Mixtures



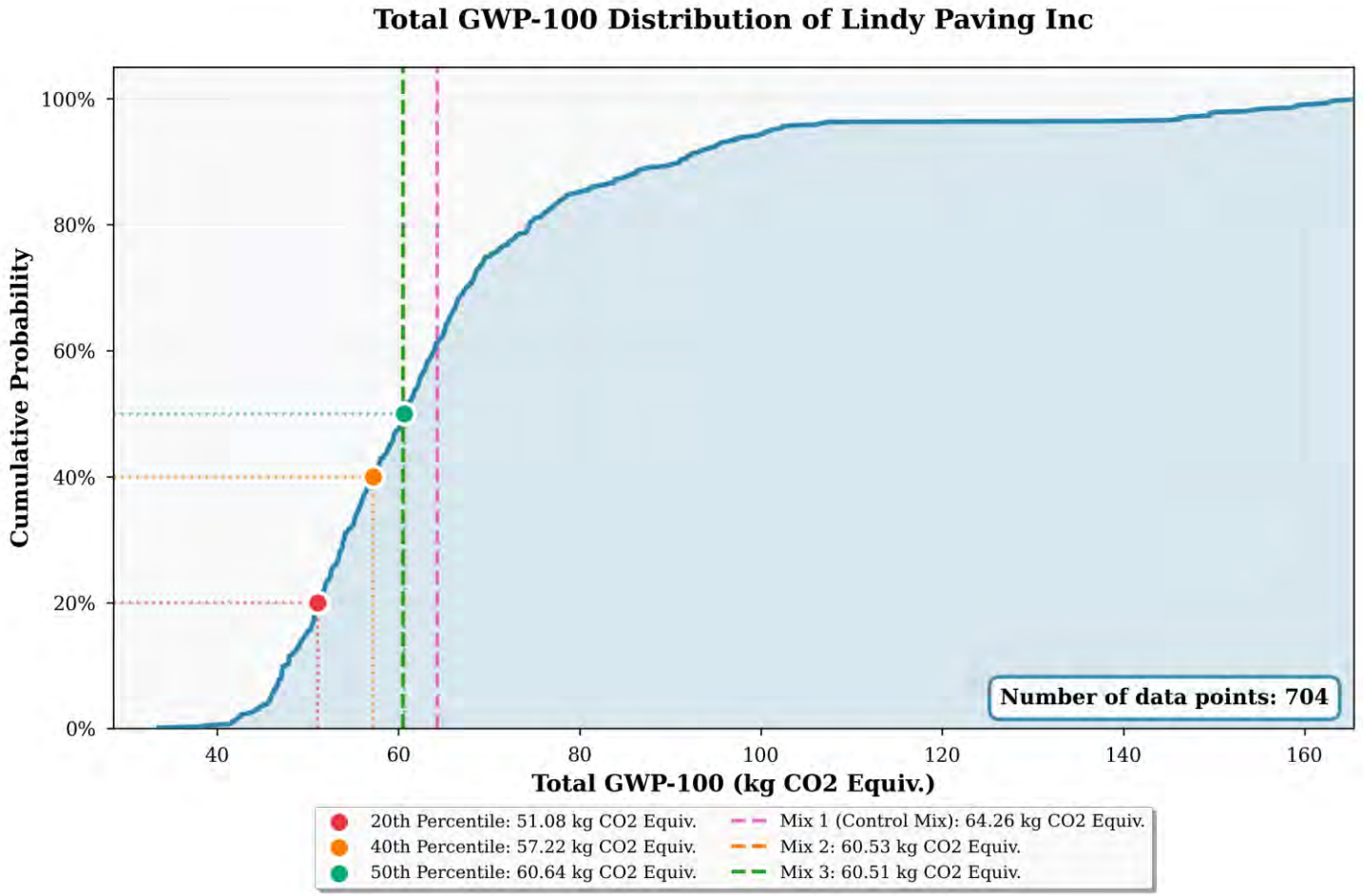
ingevity

A3 GWP-100 Lindy Mixtures



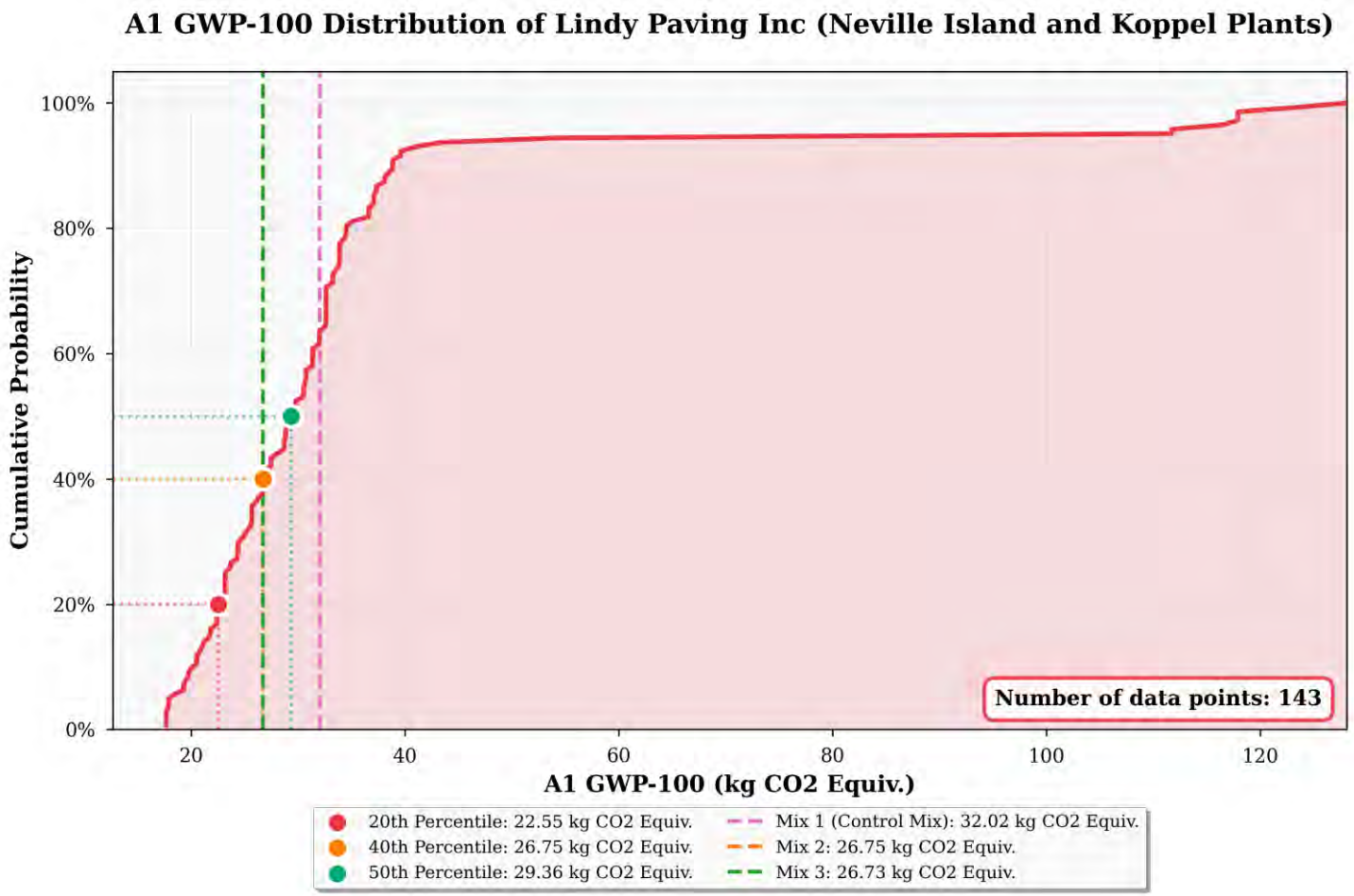
ingevity

Total GWP-100 Lindy Mixtures

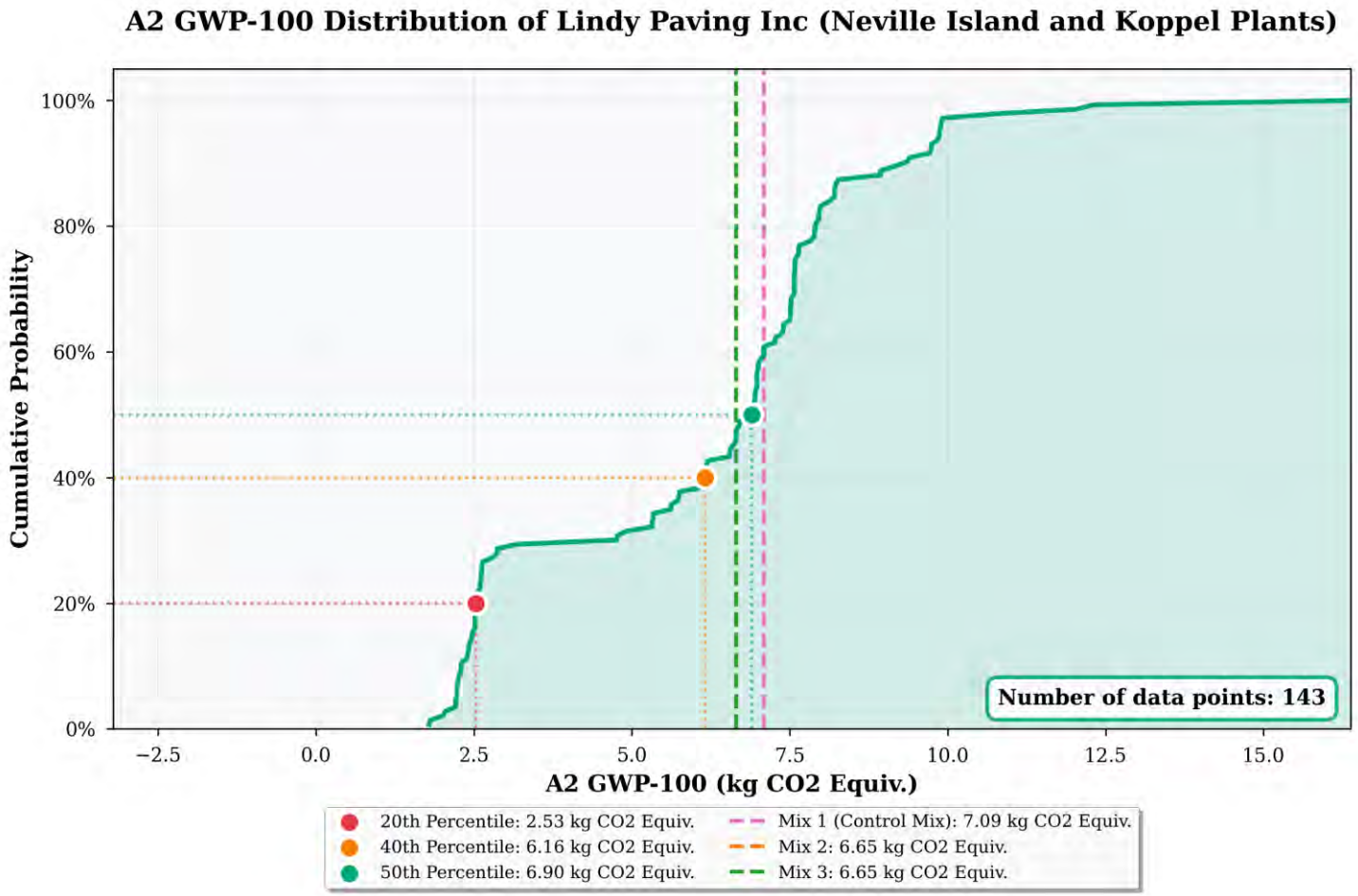


ingevity

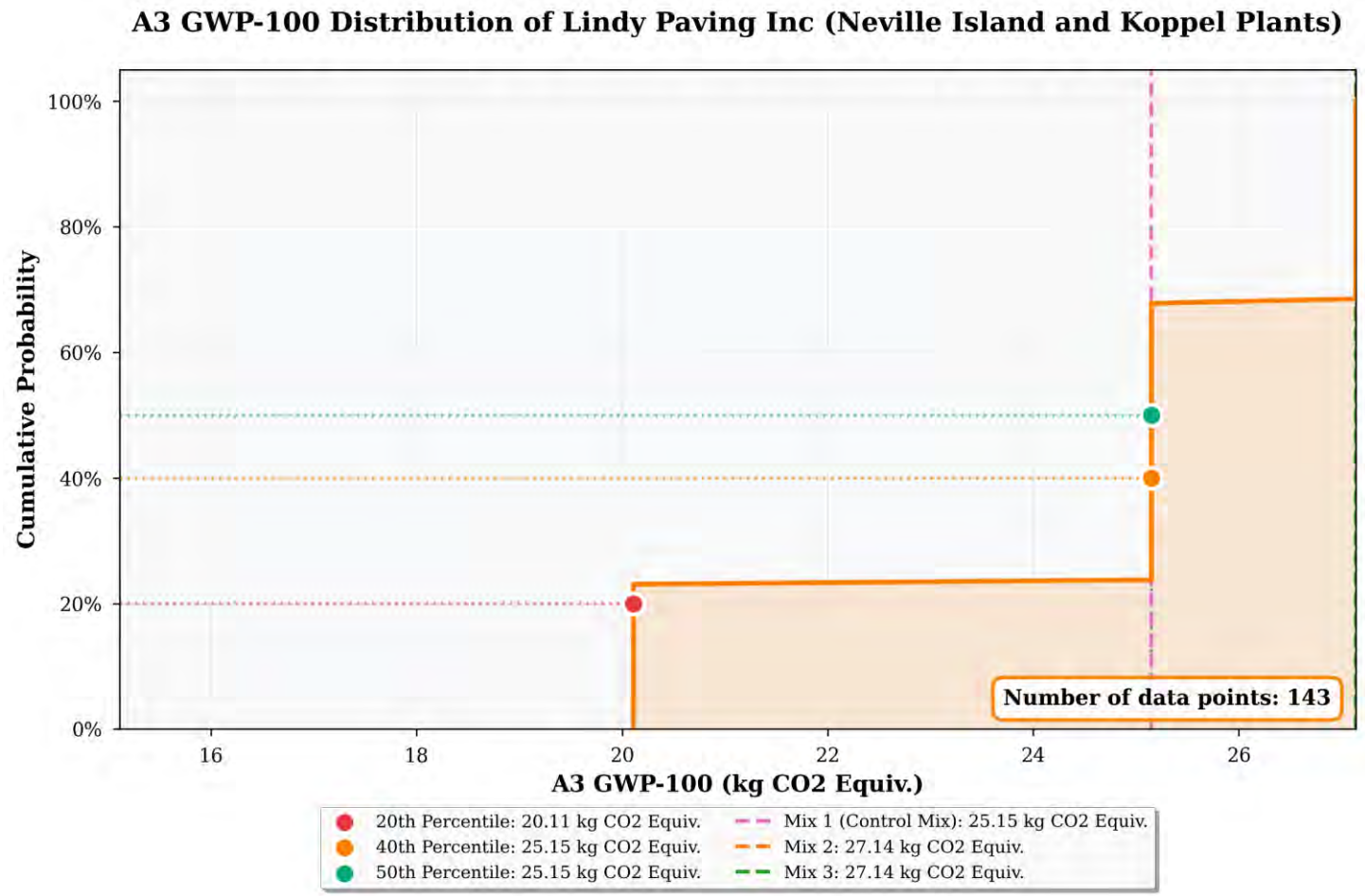
A1 GWP Lindy Paving NE and K Plant



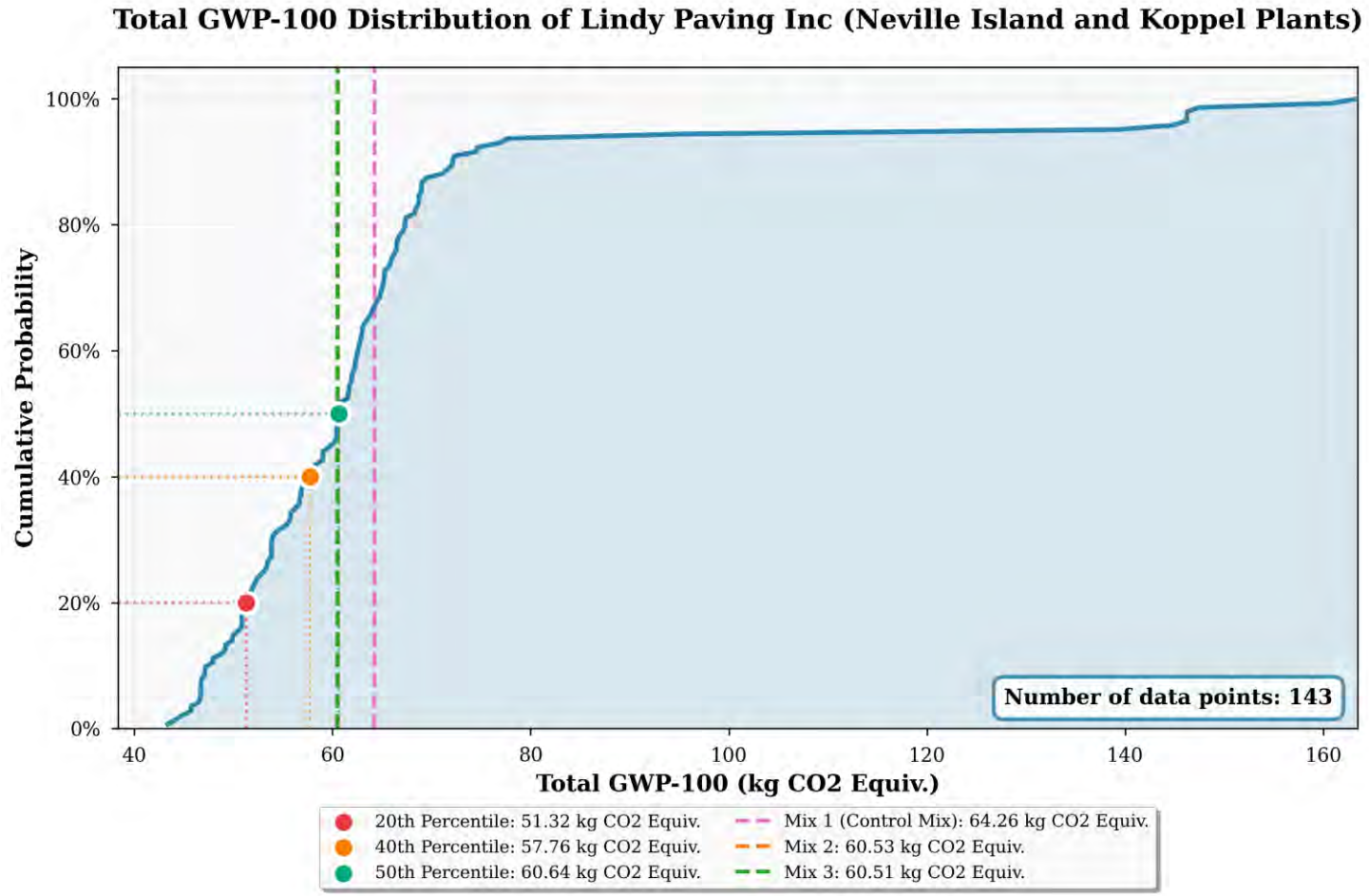
A2 GWP Lindy Paving NE and K Plant



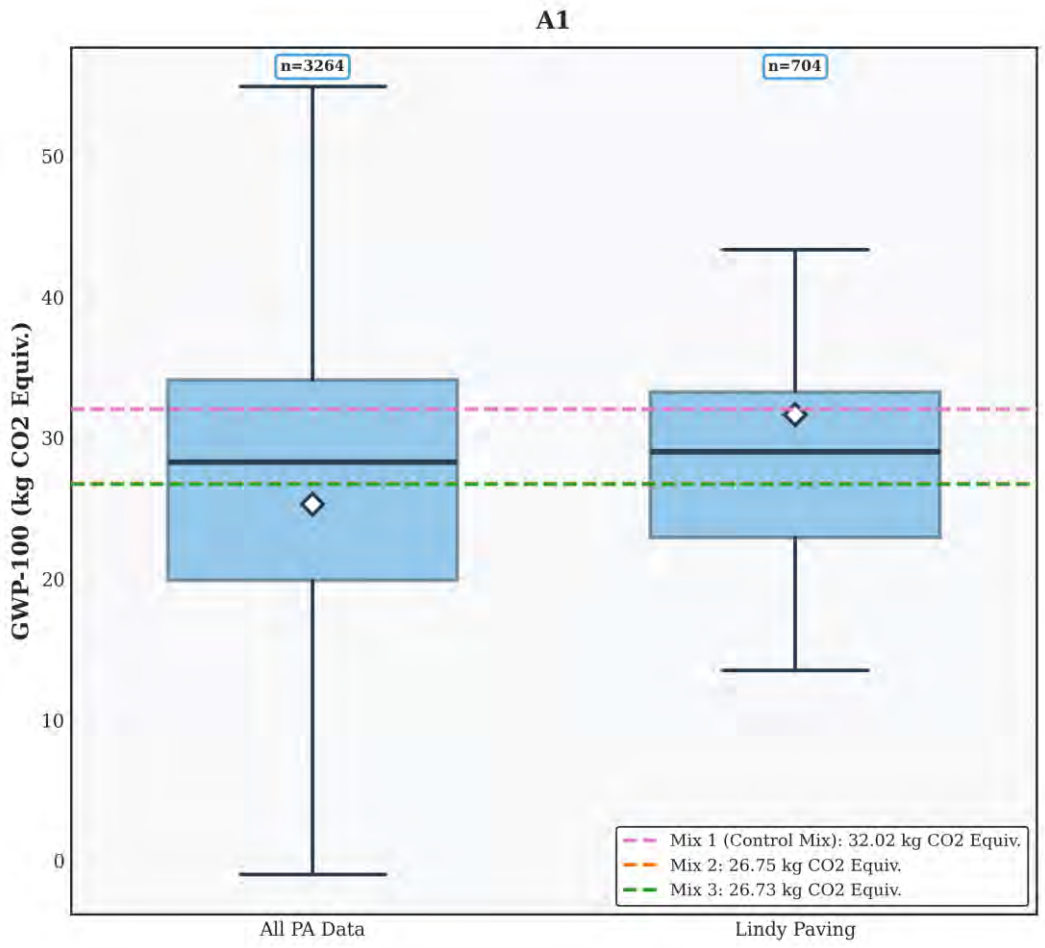
A3 GWP Lindy Paving NE and K Plant

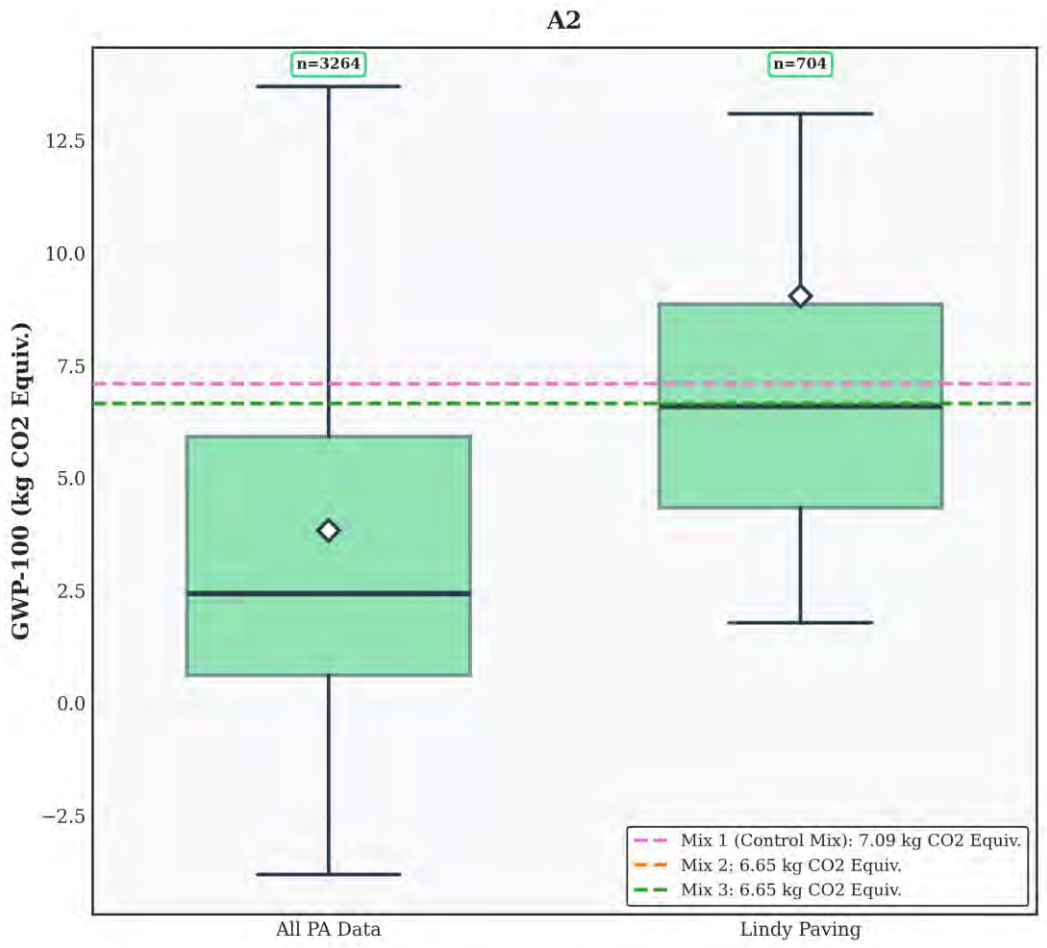


Total GWP Lindy Paving NE and K Plant

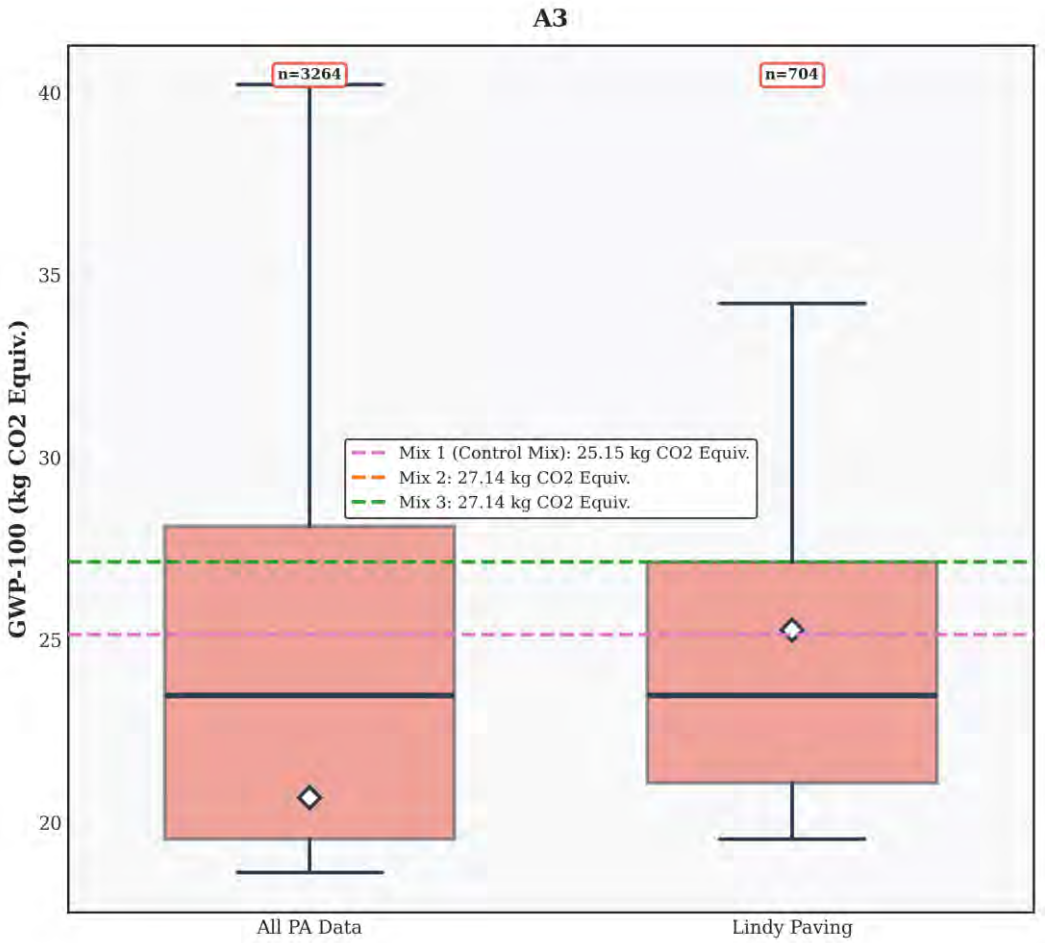


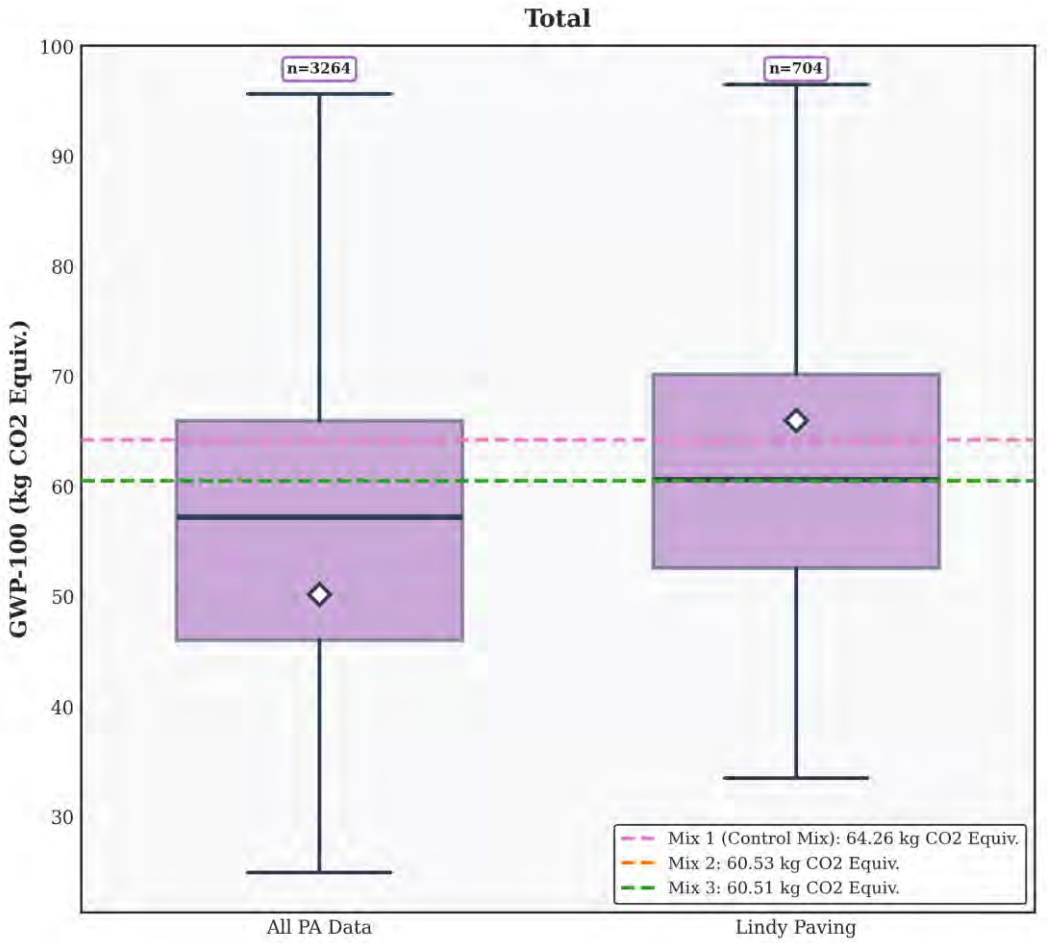
A1 and A2 All Mix EPDs PA



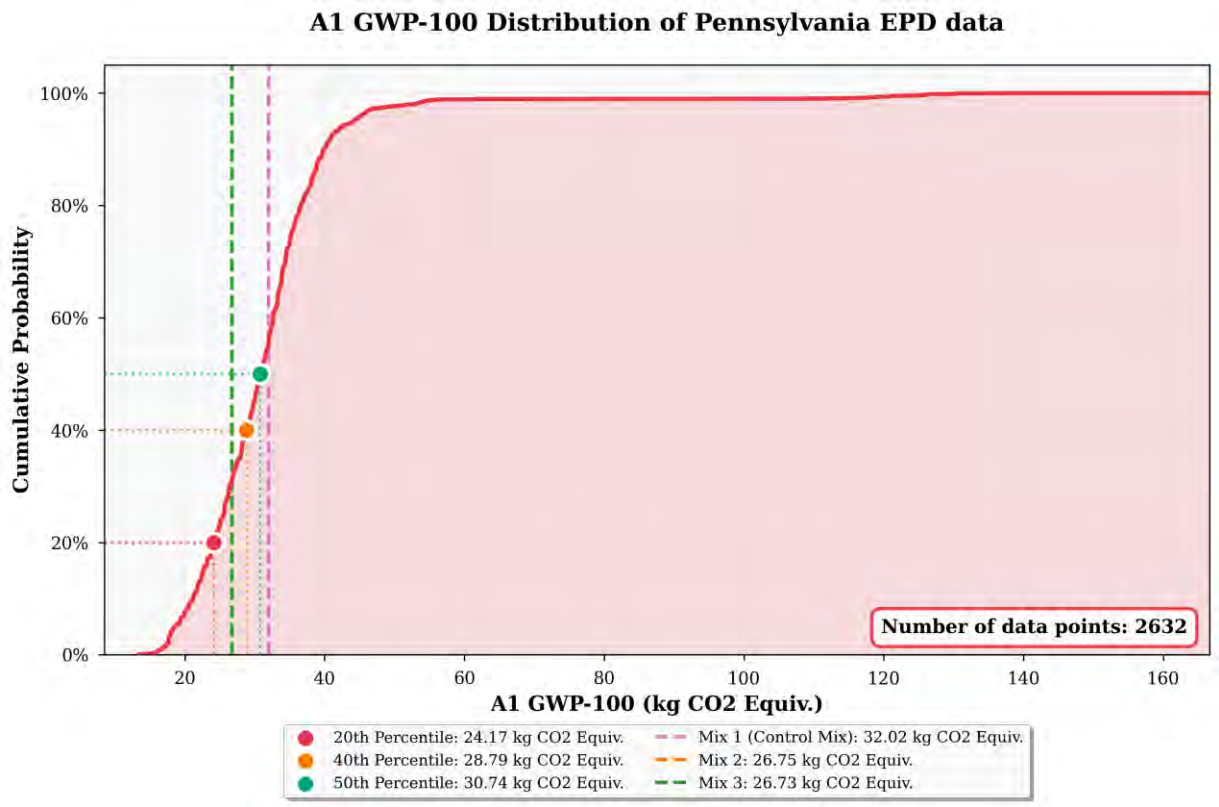


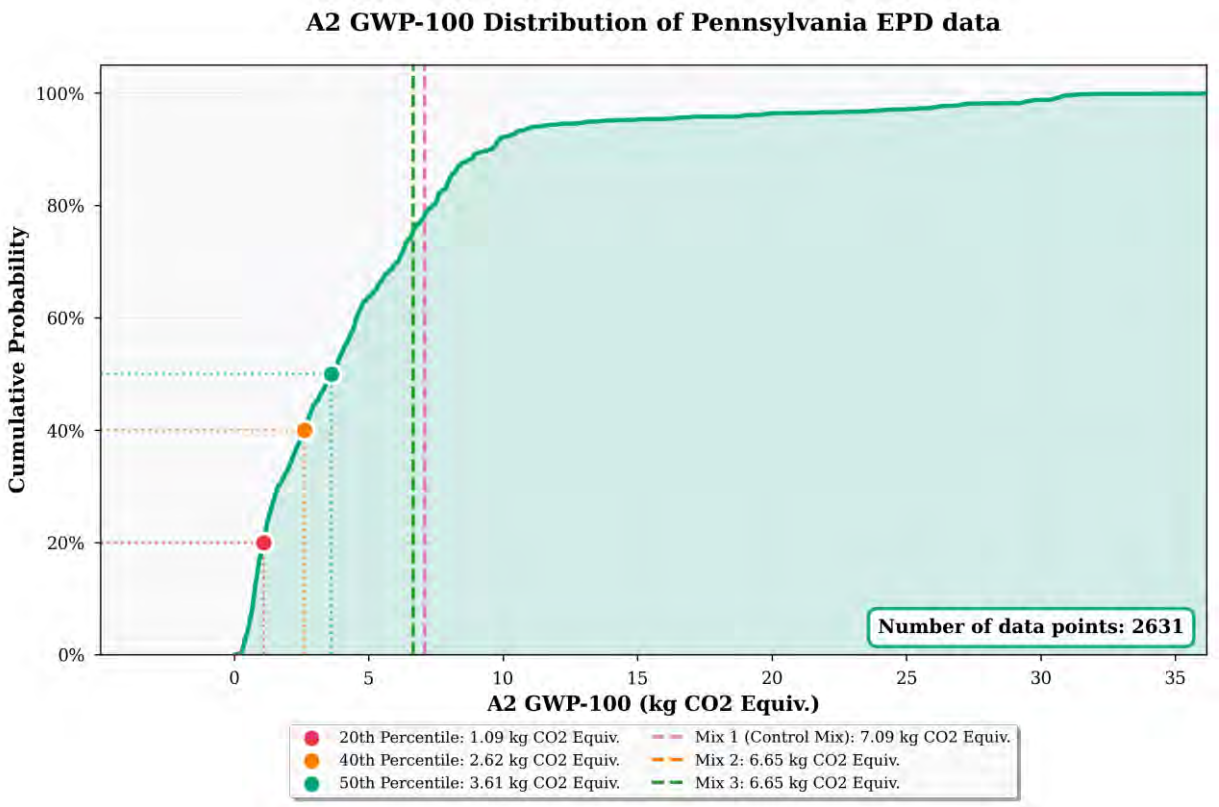
A3 and Total GWP All Mixtures PA





A1 and A2 CDG all mixtures AP





A3 and Total GWP all mixtures PA