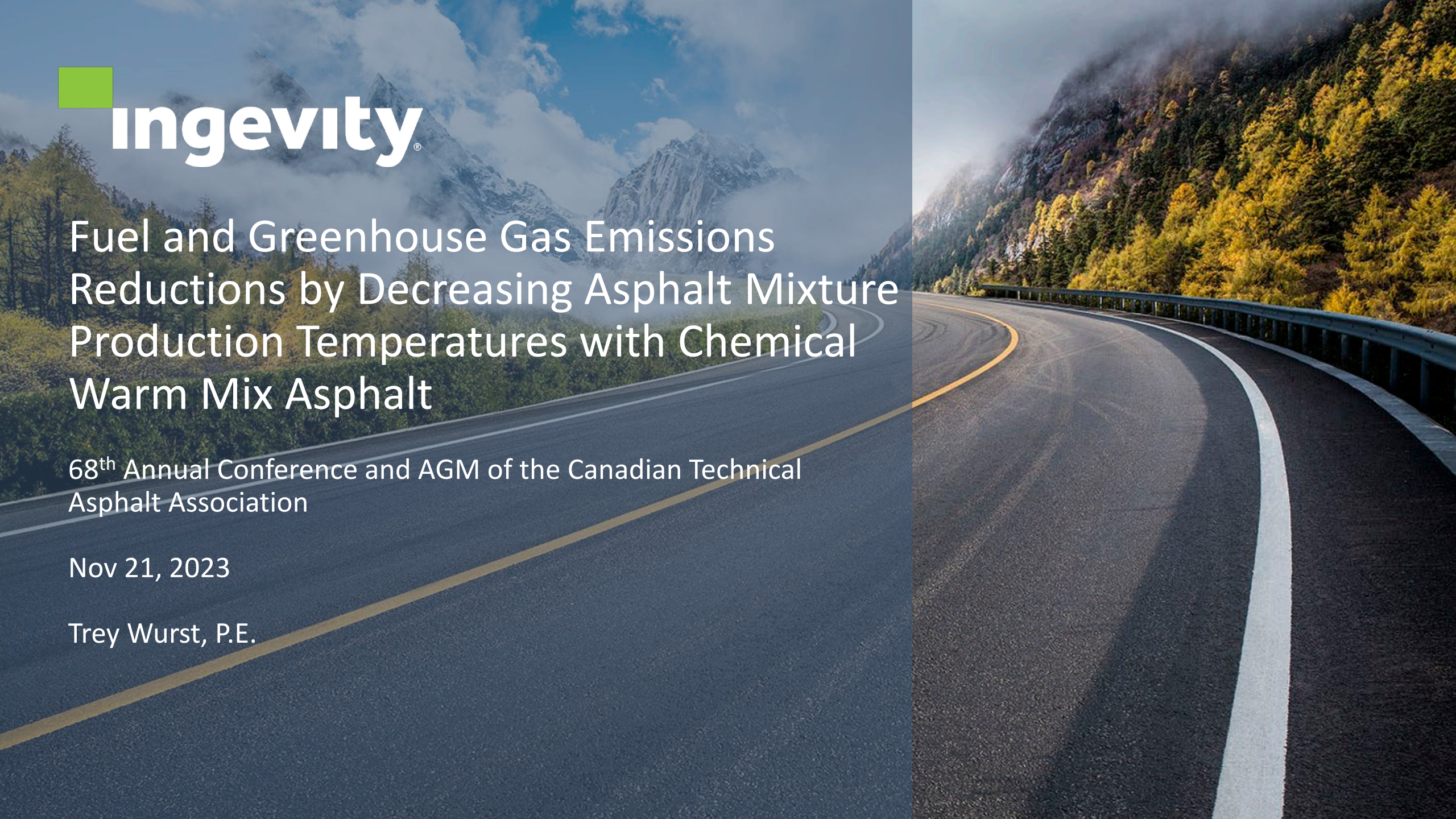


Fuel and Greenhouse Gas Emissions Reductions by Decreasing Asphalt Mixture Production Temperatures with Chemical Warm Mix Asphalt

68th Annual Conference and AGM of the Canadian Technical Asphalt Association

Nov 21, 2023

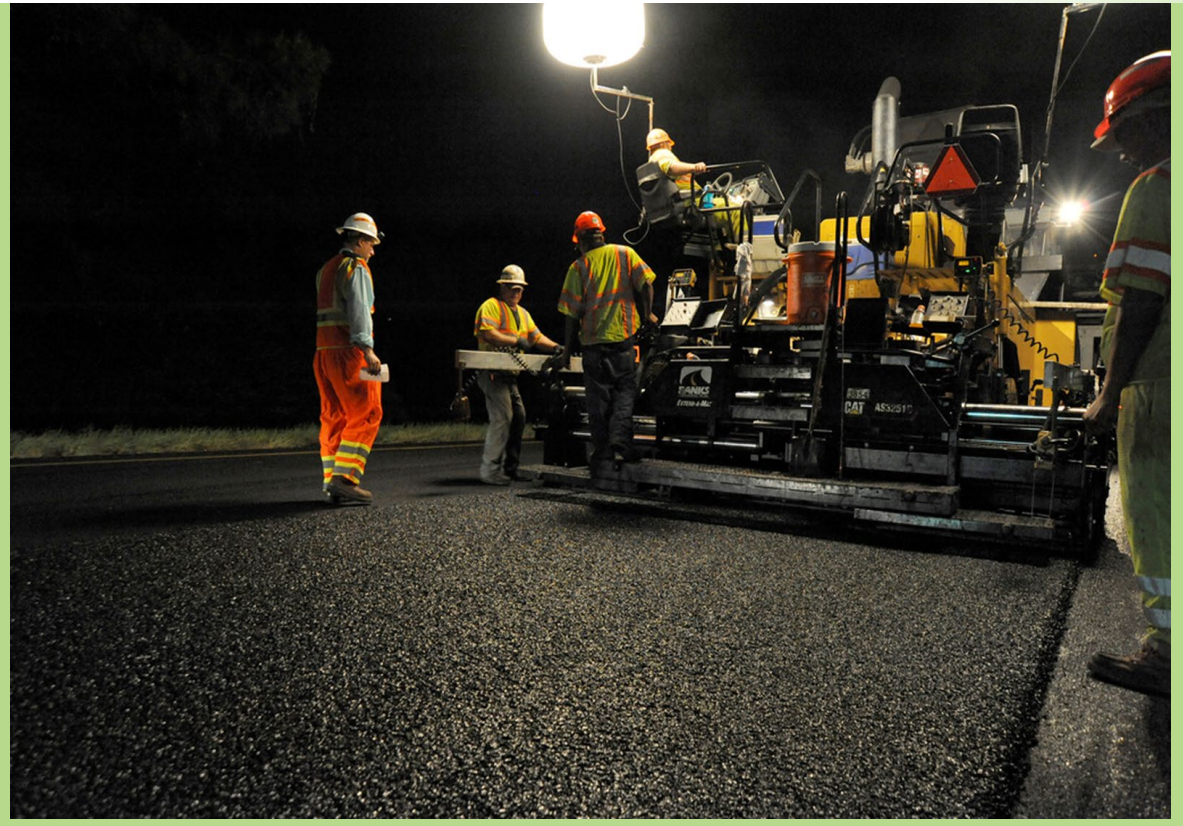
Trey Wurst, P.E.

Outline

- ❑ Introduction
- ❑ Previous Work
- ❑ Experimental Methods
- ❑ Discussion of Results
  - ❑ Particulate Emissions
  - ❑ Fuel Usage
  - ❑ CO_2 Emissions
- ❑ Conclusions
- ❑ Future Work
- ❑ Questions

Reducing Visible Emissions with Low Production Temperatures

325°F production temperature



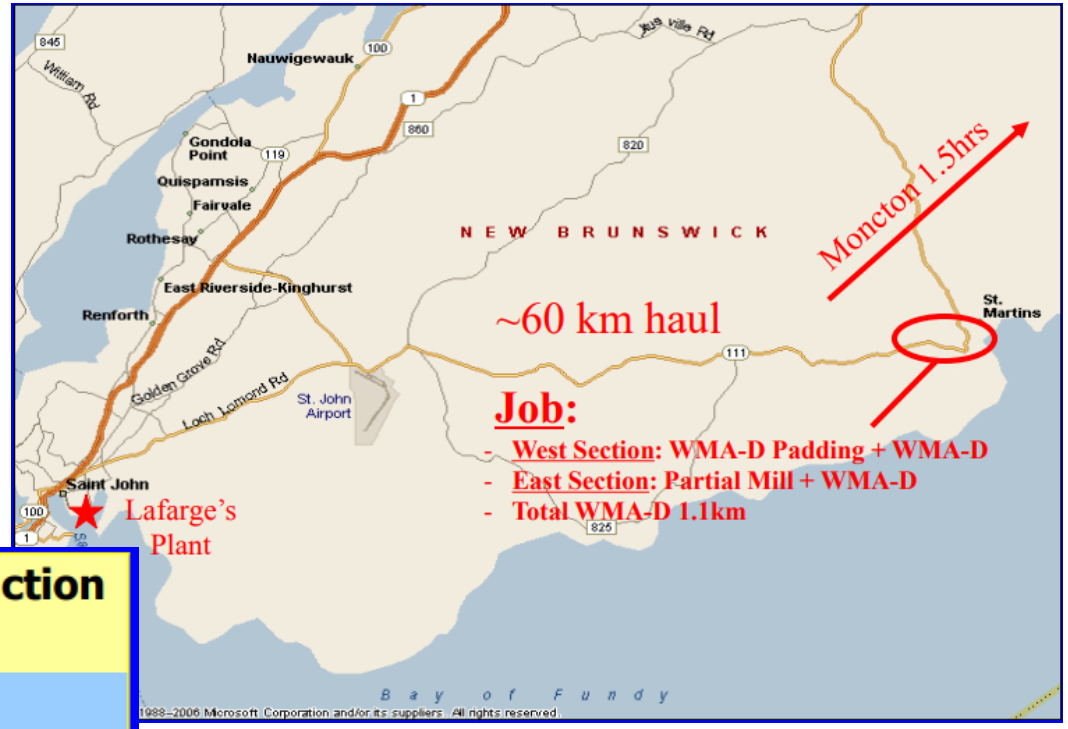
275°F production temperature

Previous Work - CTAA

Hughes, Davidson, and Cormier

Performance of Warm Mix Technology in The Province of New Brunswick

CTAA Moncton 2009

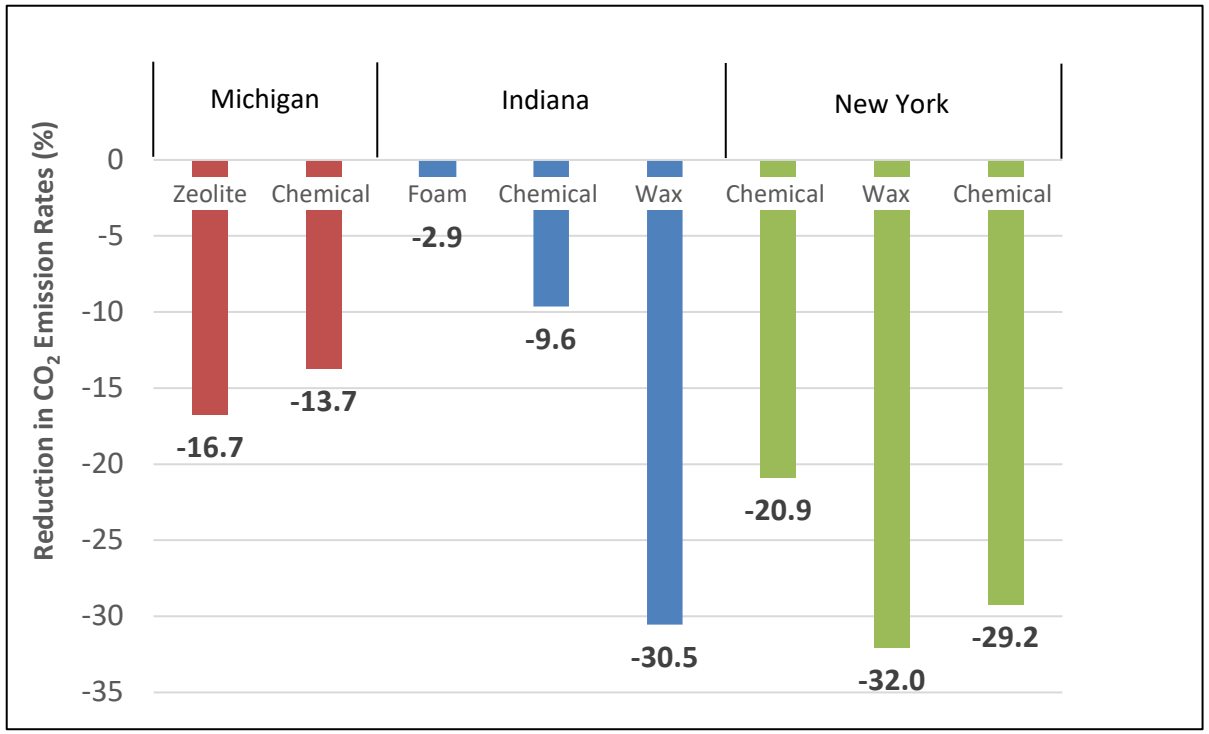


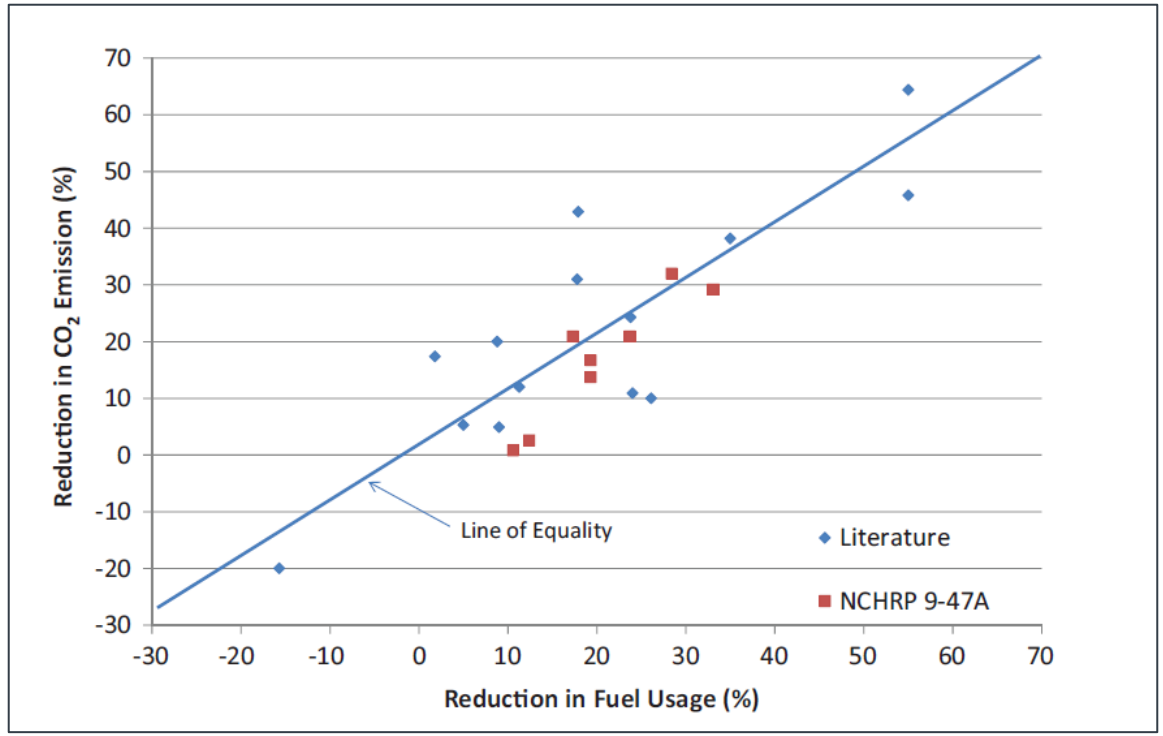
Combustion Gas	Concentration		% Reduction
	HMA	WMA	
Oxygen	15.9 %	17.4 %	
Carbon Dioxide (CO2)	3.9 %	2.8 %	28.2 %
Carbon Monoxide (CO)	28.3 ppm	20.3 ppm	28.3 %
Sulphur Dioxide (SO2)	0.1 ppm	1.3 ppm	-1300 %
Nitrogen Oxides (NOx)	63.7 ppm	41.7 ppm	34.5 %
Average Stack Temperature	118° C	94° C	
Fuel Usage litres per tonne	9 – 10	5.103 (avg.)	≈ 46 %

Previous Work

NCHRP 9-47A – "Effects of WMA on Plant Energy and Emissions and Worker Exposures to Respirable Fumes" *Prowell, Frank, Osborne, Kriech, and West, 2014*

NCHRP 9-47A measured stack emissions and fuel usage for multiple WMA technologies in relation to control HMA





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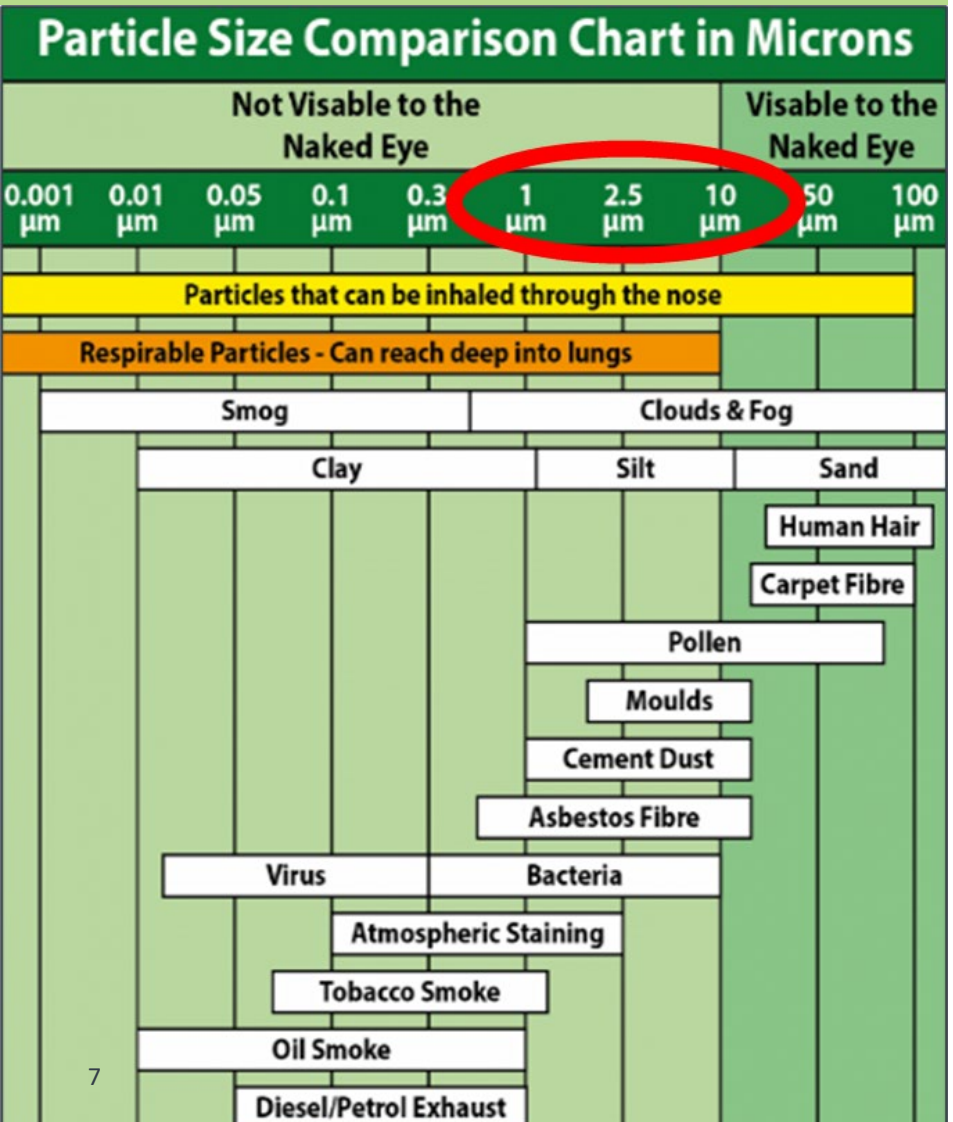
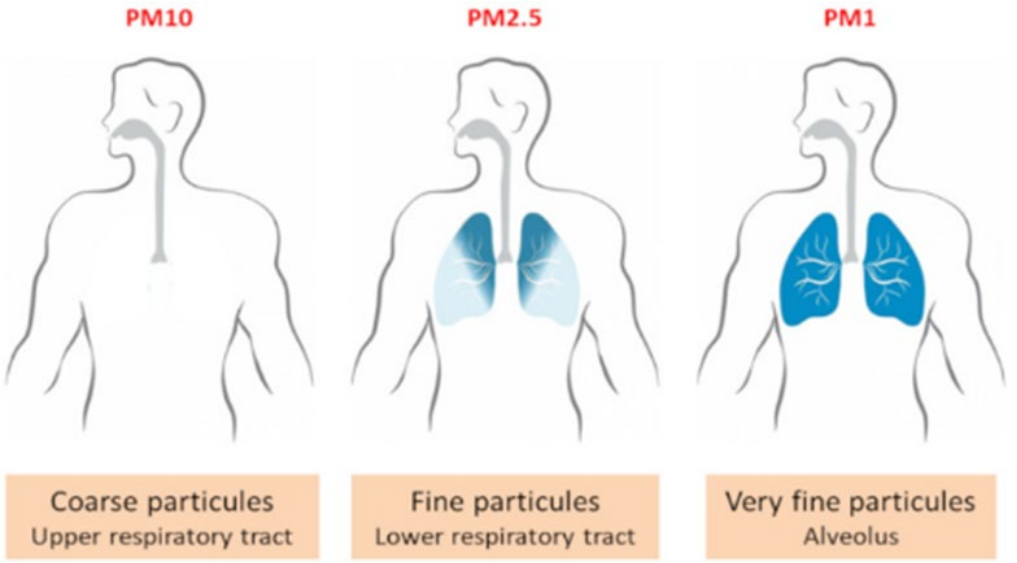
Experimental Methods

How is Particulate Matter Classified?





- Airborne particulate matter is a mixture of solids and aerosols that vary in shape, size and chemical composition.
- Particulate matter particles are classified by their aerodynamic diameter
  - PM10 →Coarse particles that are less than 10 microns in diameter
  - PM2.5 → Fine particles that are less than 2.5 microns in diameter
  - PM1.0 →Very fine particles that are less than 1 micron in diameter
- Particle size is important for classification because particles less than 10 microns are inhalable into the lungs with fine particles penetrating deep into the lungs, which may induce adverse health effects.

Particulate Emissions Devices at the Plant

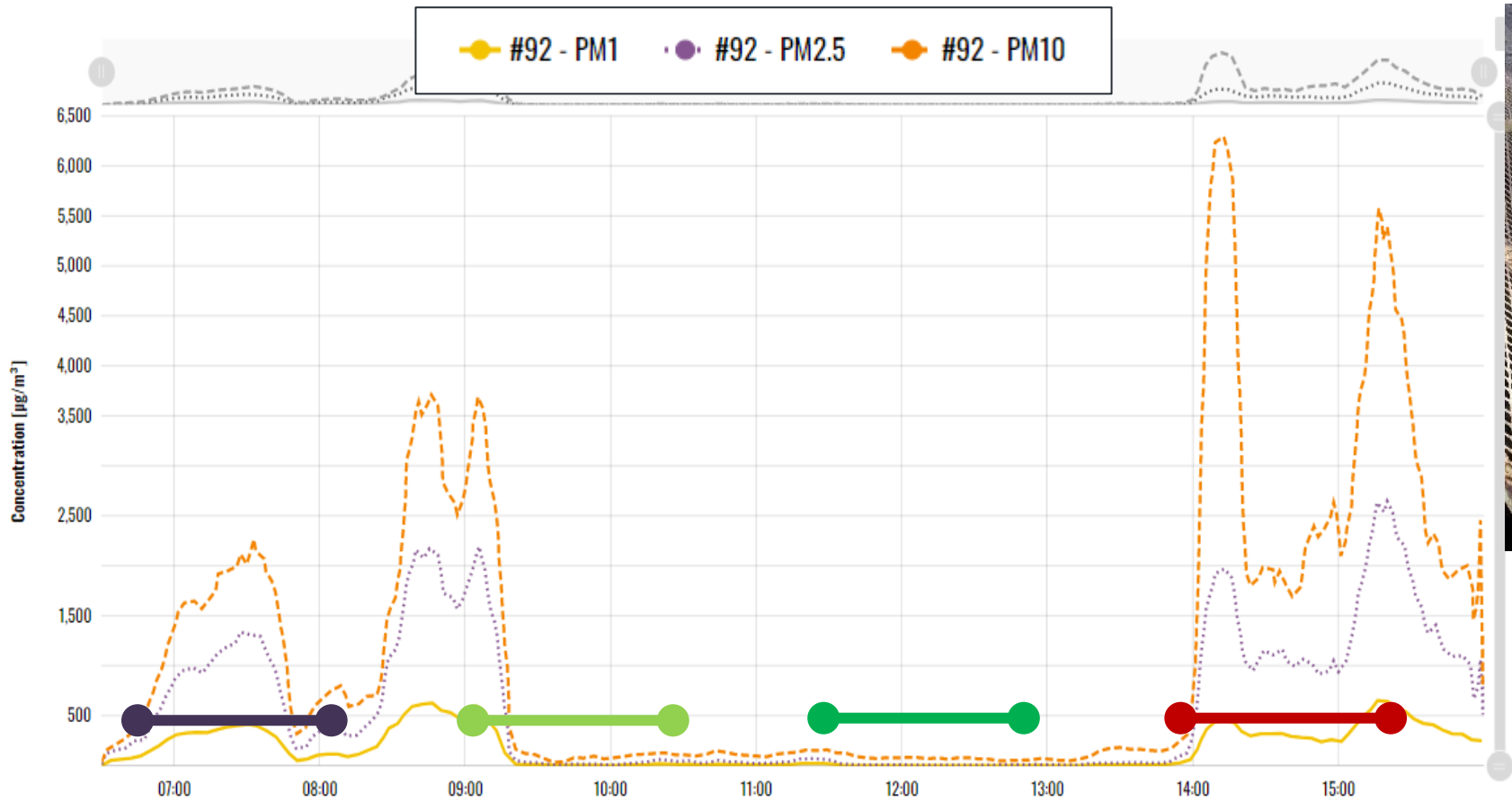
One particulate analyzer placed at the load out

One particulate analyzer placed at the top of the silo

One particulate analyzer placed over the chute

APT Device

Emissions Reductions Benefits with True WMA



Run #1 AVG 305F Mix Temp

Run #2 280F AVG Mix Temp

Run #3 260F AVG Mix Temp

Run #4 325F AVG Mix Temp

APT Device

Fuel Usage Measurements

CO_2 - Stack Testing

Mix Design Variables

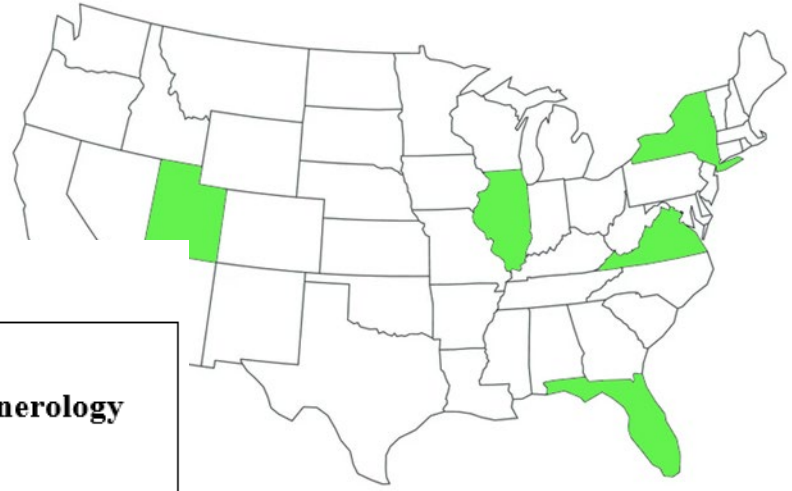
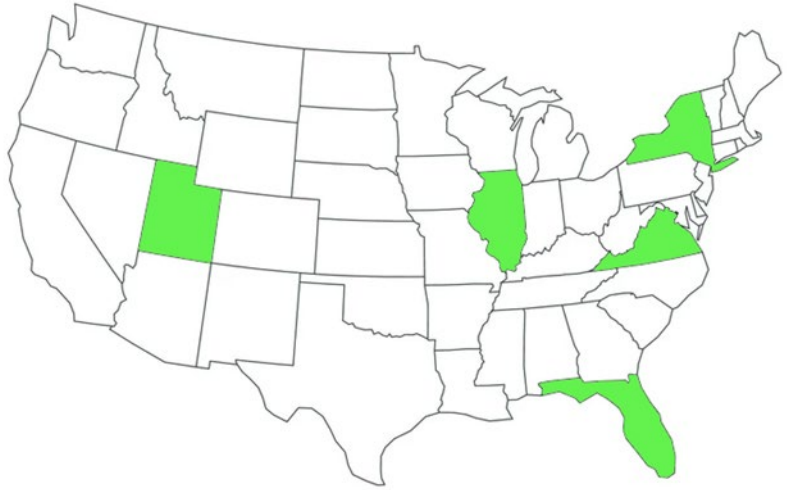


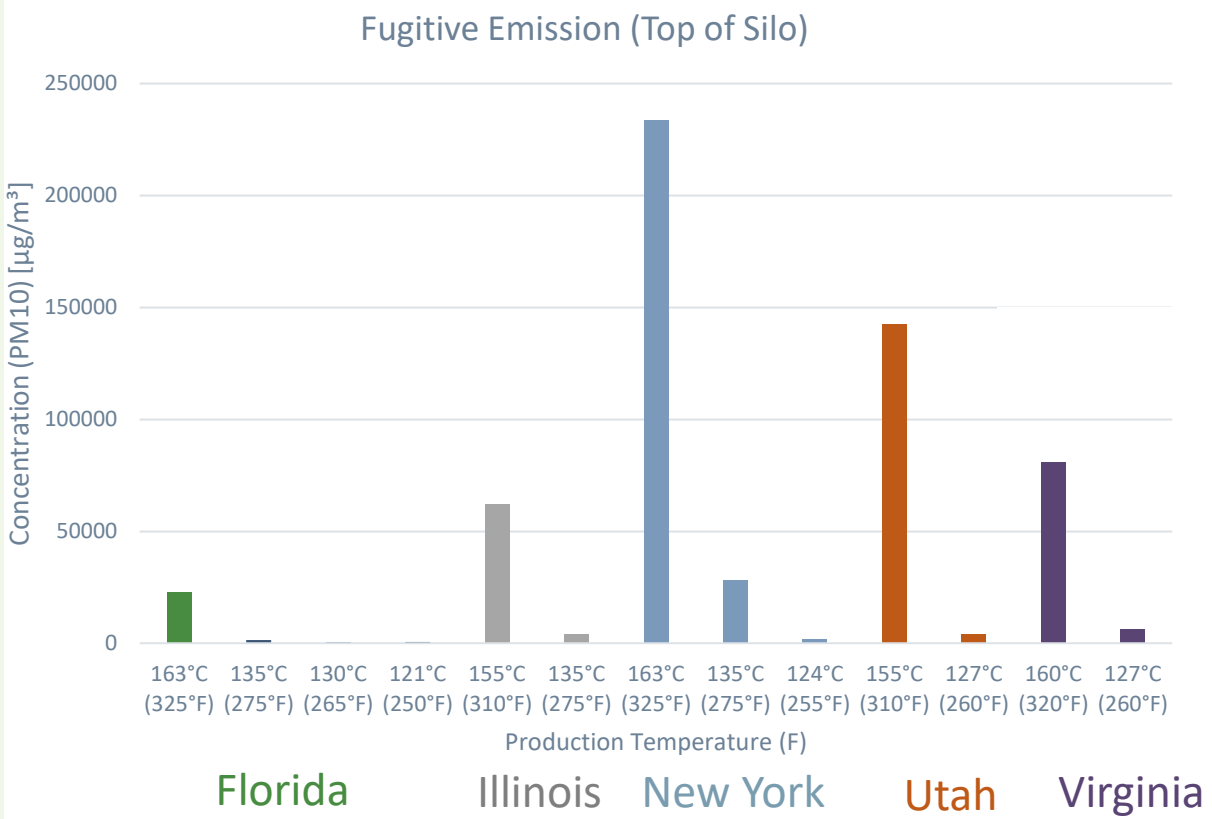
Table 1- Mix Design Characteristics and Aggregate Mineralogy

Location	RAP Content (%)	Total Binder Content (%)	Virgin Binder Content (%)	Virgin Binder Grade	N Max Aggregate Size (mm)	Aggregate Minerology
Florida	40	5.9	3.6	PG 52-28	9.5	Nova Scotia Granite River-bottom Sand
Illinois	40 (3% RAS)	5.4	3.4	PG 58-28	19.0	Dolomitic Limestone
New York	20	6.0	4.7	PG 64V-22	9.5	Limestone (78%) Graywacke (sandstone) (22%)
Utah	15	5.1	4.4	PG 64-28	12.5	Quartzite
Virginia	30	5.6	3.9	PG 64S-22	9.5	Diabase Traprock
Mississippi	20%	6.1	5.2	PG 67-22	9.5	Crushed Gravel (36%) Limestone (33%) Sand (10%)

Fugitive Emissions Data

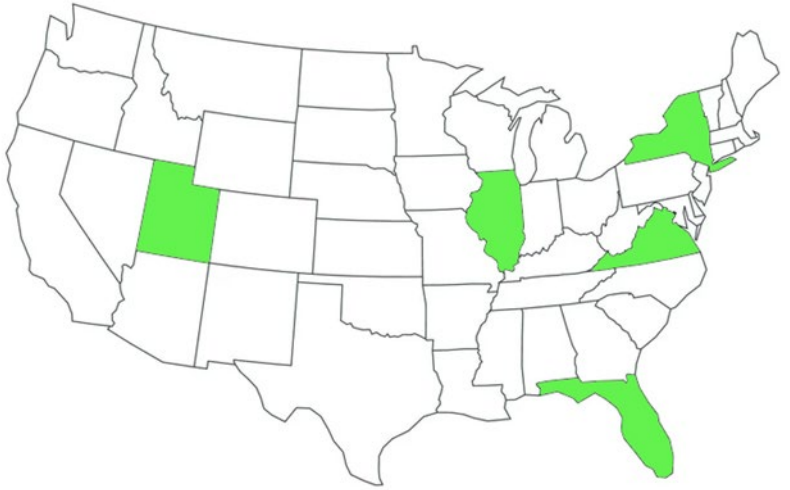
WMA Plant Fugitive Emissions Data 2022





PM10 Concentration Plant					
Location	Top of Silo			Silo Loadout	
	Production Temperature	Concentration (PM10) [µg/m³]	Percent Reduction	Concentration (PM10) [µg/m³]	Percent Reduction
Florida	163°C (325°F)	22733		6387	
	135°C (275°F)	1437	94%	1885	70%
	130°C (265°F)	483	98%	283	96%
	121°C (250°F)	704	97%	432	93%
Illinois	155°C (310°F)	62261		119749	
	135°C (275°F)	4137	93%	632	99%
New York	163°C (325°F)	233676		13364	
	135°C (275°F)	28331	88%	1247	91%
	124°C (255°F)	1793	99%	2060	85%
Virginia	155°C (310°F)	142569		56267	
	127°C (260°F)	4254	97%	9472	83%
Utah	160°C (320°F)	80882		70905	
	127°C (260°F)	6240	92%	9814	86%

WMA Plant Fugitive Emissions Data 2022



PM10 Concentration Plant					
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	135°C (275°F)	4137	93%	632	99%
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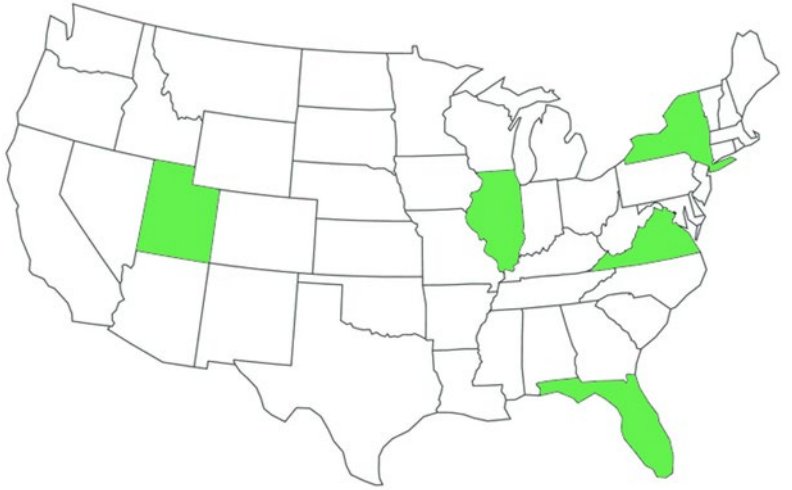
	135°C (275°F)	28331	88%	1247	91%
	124°C (255°F)	1793	99%	2060	85%
Virginia	155°C (310°F)	142569		56267	
	127°C (260°F)	4254	97%	9472	83%
Utah	160°C (320°F)	80882		70905	
	127°C (260°F)	6240	92%	9814	86%

PM2.5 Concentration – Plant					
Location	Top of Silo			Silo Loadout	
	Production Temperature	Concentration (PM2.5) [µg/m³]	Percent Reduction	Concentration (PM2.5) [µg/m³]	Percent Reduction
Florida	163°C (325°F)	3574		893	
	135°C (275°F)	337	91%	569	36%
	130°C (265°F)	154	96%	104	88%
	121°C (250°F)	132	96%	208	77%
Illinois	155°C (310°F)	5841		2123	
	135°C (275°F)	2570	56%	311	85%
New York	163°C (325°F)	16526		685	
	135°C (275°F)	7970	52%	392	43%
	124°C (255°F)	1029	94%	144	79%
Virginia	155°C (310°F)	10383		3695	
	127°C (260°F)	1871	82%	1607	57%
Utah	160°C (320°F)	2120		3063	
	127°C (260°F)	910	57%	878	71%

WMA Paver Fugitive Emissions Data 2022



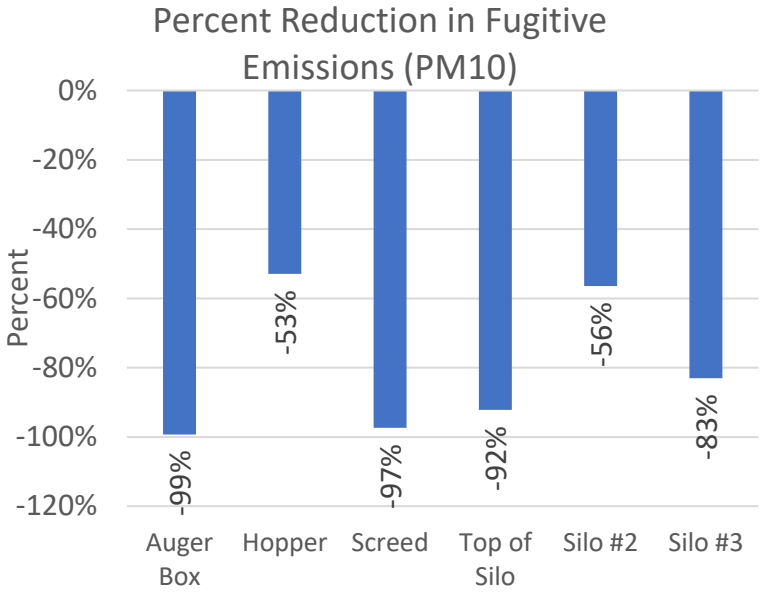
PM10 Concentration Paver					
Location	Screed Operator			Center of Screed	
	Production Temperature	Concentration (PM10) [µg/m³]	Percent Reduction	Concentration (PM10) [µg/m³]	Percent Reduction
Florida	163°C (325°F)	1497		3859	
	135°C (275°F)	156	90%	152	96%
	130°C (265°F)	34	98%	121	97%
	121°C (250°F)	36	98%	94	98%
Illinois	155°C (310°F)	2470		N/A	
	135°C (275°F)	398	84%	N/A	
New York	163°C (325°F)	25989		35418	
	135°C (275°F)	3860	85%	3039	91%
	124°C (255°F)	7147	73%	3954	89%
Virginia	155°C (310°F)	5765		386	
	127°C (260°F)	540	91%	84	78%
Utah	160°C (320°F)	61783		107691	
	127°C (260°F)	1680	97%	875	99%

PM2.5 Concentration – Paver					
Location	Screed Operator			Center of Screed	
	Production Temperature	Concentration (PM2.5) [µg/m³]	Percent Reduction	Concentration (PM2.5) [µg/m³]	Percent Reduction
Florida	163°C (325°F)	572		1373	
	135°C (275°F)	70	88%	49	96%
	130°C (265°F)	7	99%	16	99%
	121°C (250°F)	13	98%	24	98%
Illinois	155°C (310°F)	922		N/A	
	135°C (275°F)	111	88%	N/A	
New York	163°C (325°F)	7514		7795	
	135°C (275°F)	1228	84%	1263	84%
	124°C (255°F)	1803	76%	1144	85%
Virginia	155°C (310°F)	2078		90	
	127°C (260°F)	200	90%	22	76%
Utah	160°C (320°F)	8108		10742	
	127°C (260°F)	670	92%	257	98%

WMA Plant Fugitive Emissions Data 2022

Project details from Contractor **(Utah)**

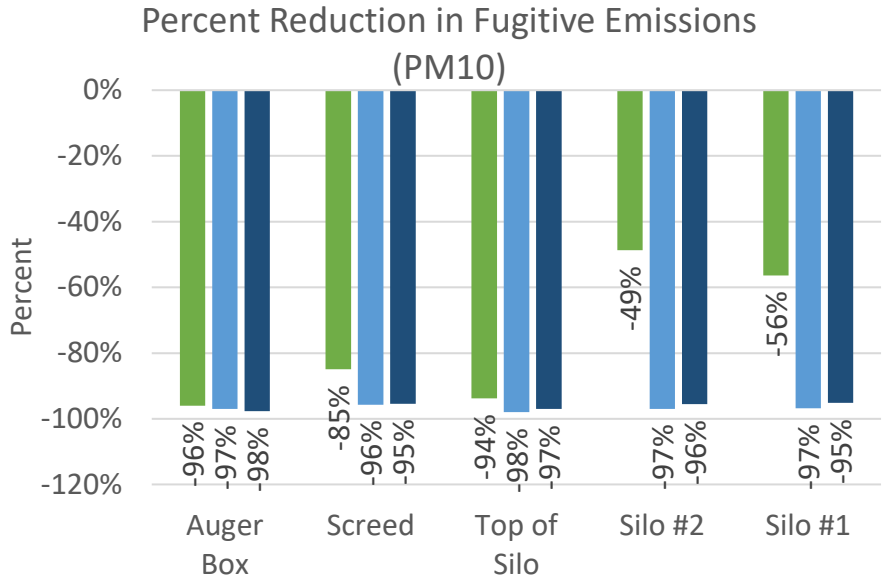
- 360 Tons/hr run rate
- Gencor Counter Flow Drum
- 15% RAP Content



315°F → **260°F**

Project Details from Contractor **(Florida)**

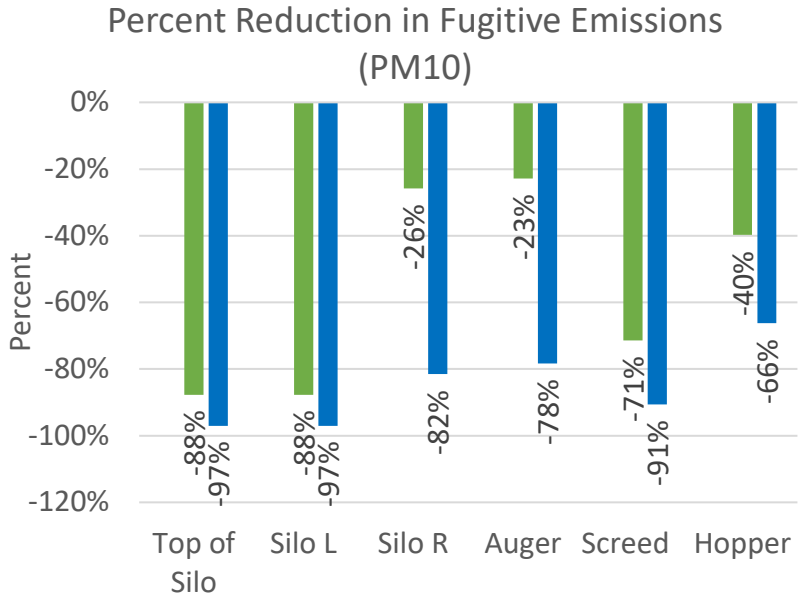
- 200 Tons/hr run rate
- Astec Double Barrel Green
- 40% RAP Content



325°F → **275°F** → **265°F** → **250°F**

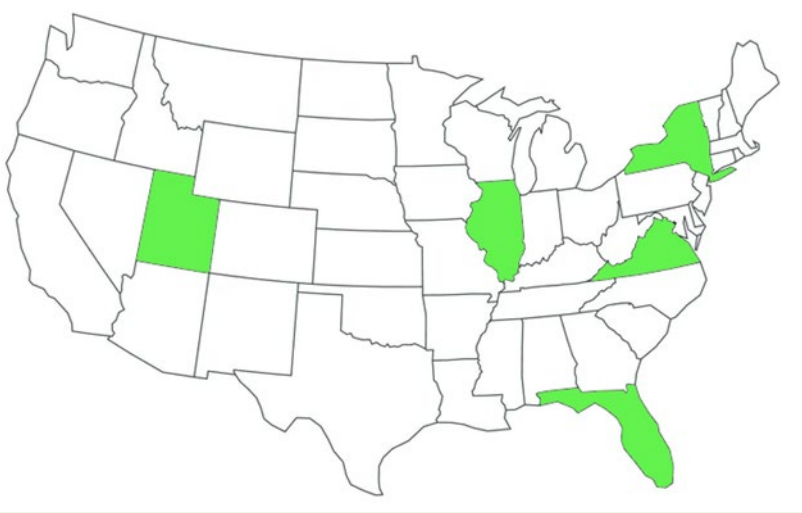
Project Details from Contractor **(Virginia)**

- 290 Tons/hr run rate
- Astec Double Barrel Green
- 30% RAP Content



310°F → **285°F** → **260°F**

2022 Low Temperature WMA Data



Fugitive Emissions Reductions by Location (PM10)

Note: Average Temp Reduction 51°F-55°F

Top of Silo

92%

Silo Loadout

80%

Screed Operator

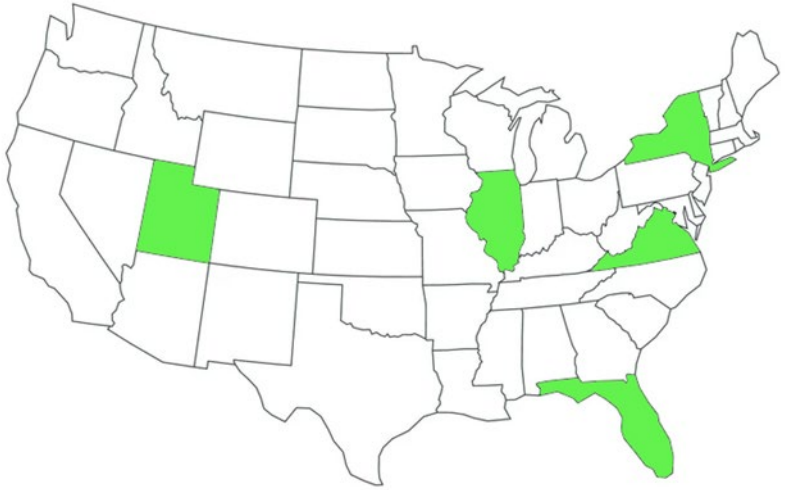
88%

Center of Screed

92%

Note: Average Reduction across the projects

2022 Low Temperature WMA Data



Fugitive Emissions Reductions by Location (PM2.5)

Note: Average Temp Reduction 51°F-55°F

Top of Silo

75%

Silo Loadout

67%

Screed Operator

90%

Center of Screed

87%

Note: Average Reduction across the projects

Reducing Visible Emissions with Low Production Temperatures

Standard Asphalt Mix at 325°F

Mix with Evotherm at 50°F Reduction

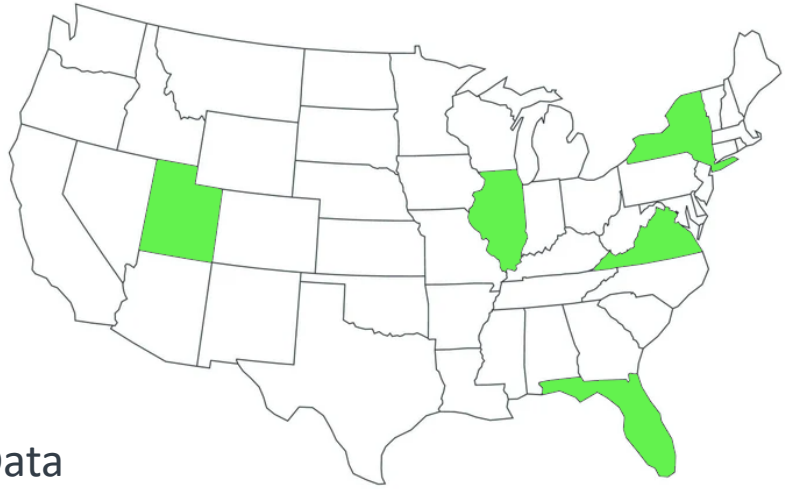
Reducing Visible Emissions with Low Production Temperatures

Smoke – Standard Hot Mix Asphalt at 315F

No Smoke – Mix with Chemical WMA at 260F

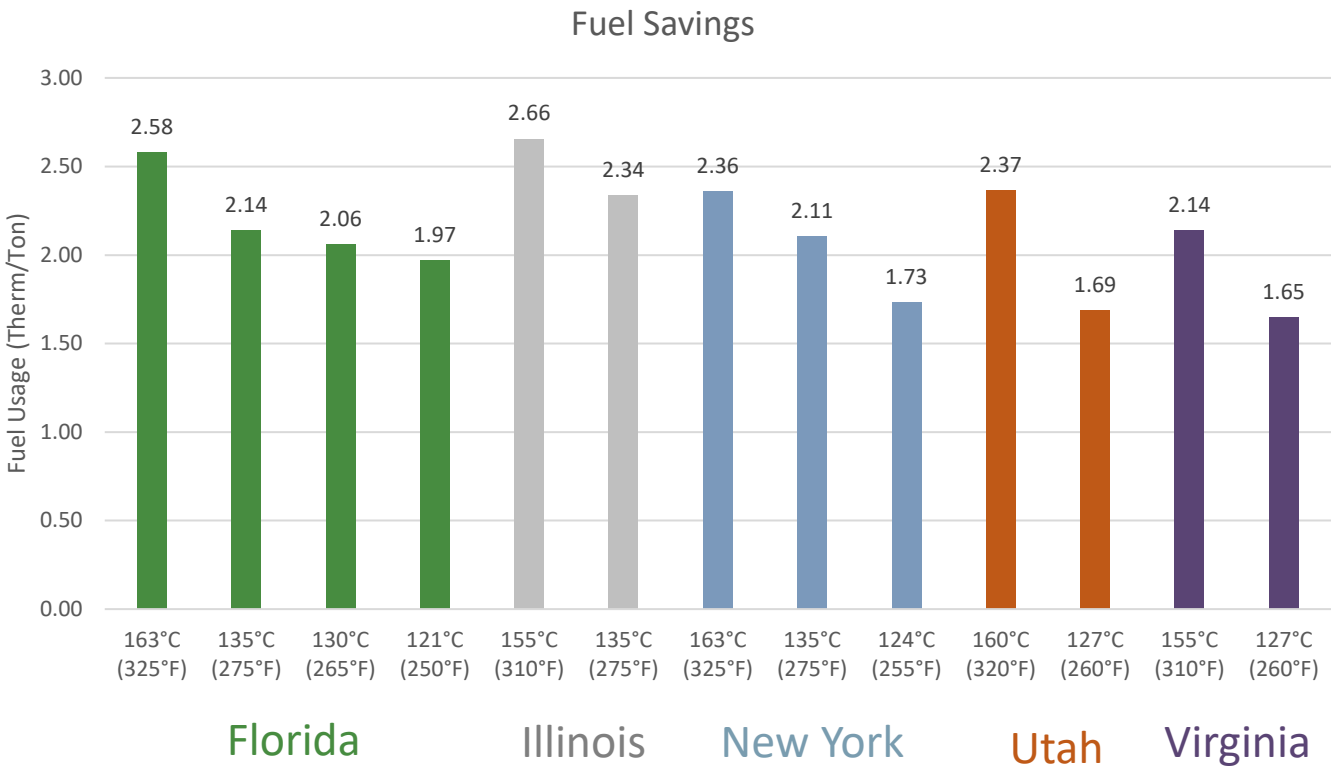
Fuel Usage and CO_2 Data

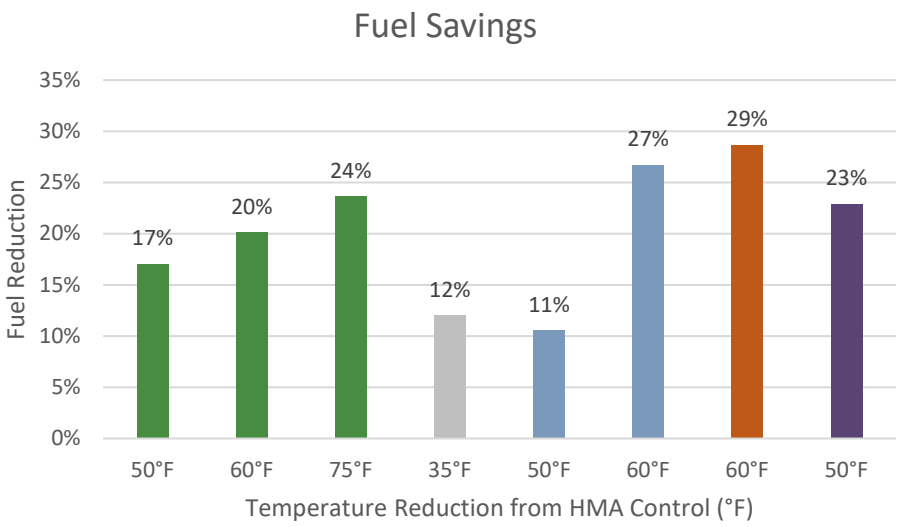
Fuel Usage Reduction



Average Data

55.0°F Temperature Reduction
20.4% Reduction in natural gas consumed



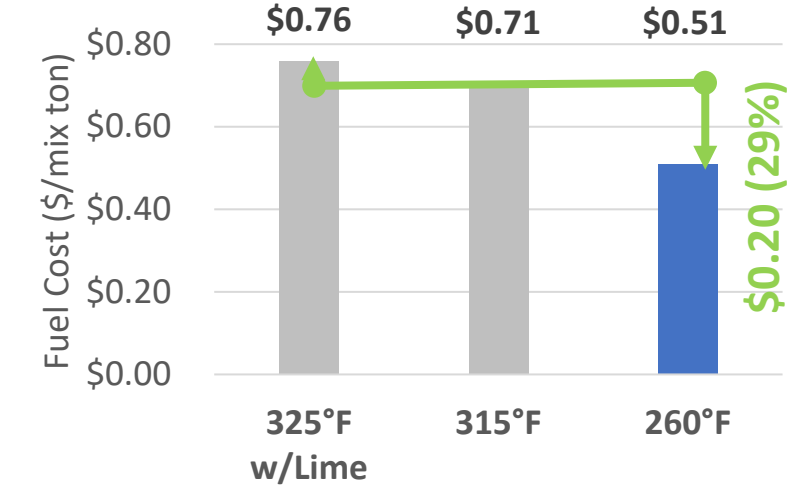


WMA Plant Fuel Consumption 2022

Note: Natural gas fuel $3.00/MMBtu assumption

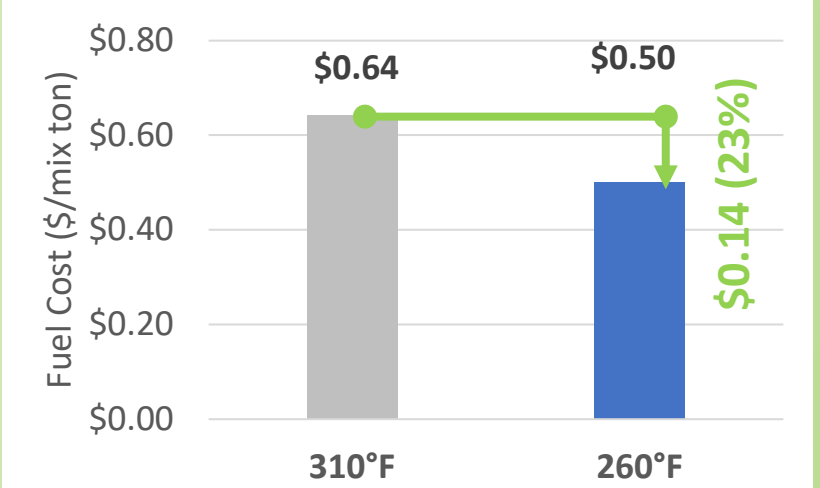
Utah Contractor
- 360 Tons/hr
- Gencor Counter Flow
- 15% RAP
- 250k Mix Tons/yr
- $50k Savings (single plant at 260°F)

CO_2 Reduction 26.0%



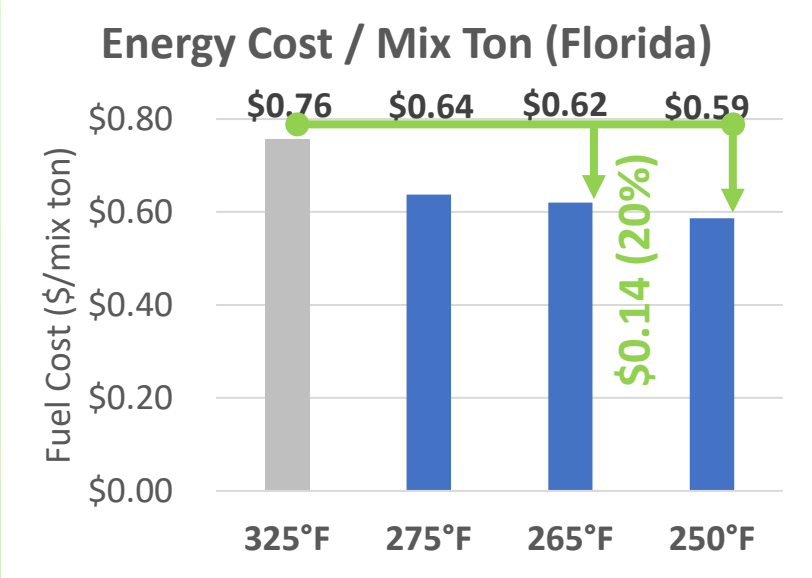
Virginia Contractor
- 290 Tons/hr
- Astec Double Barrel
- 30% RAP Content
- 250k Mix Tons/yr
- $35k Savings (single plant at 260°F)

CO_2 Reduction 21.8%



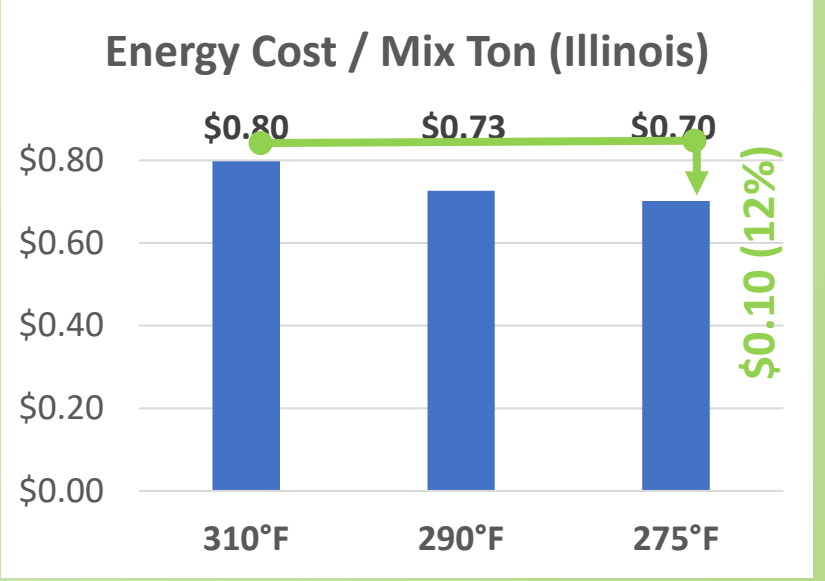
Florida Contractor
- 200 Tons/hr
- Astec Double Barrel
- 40% RAP
- 150k Mix Tons/yr
- $21k Savings (single plant at 265°F)

CO_2 Reduction 25.1%

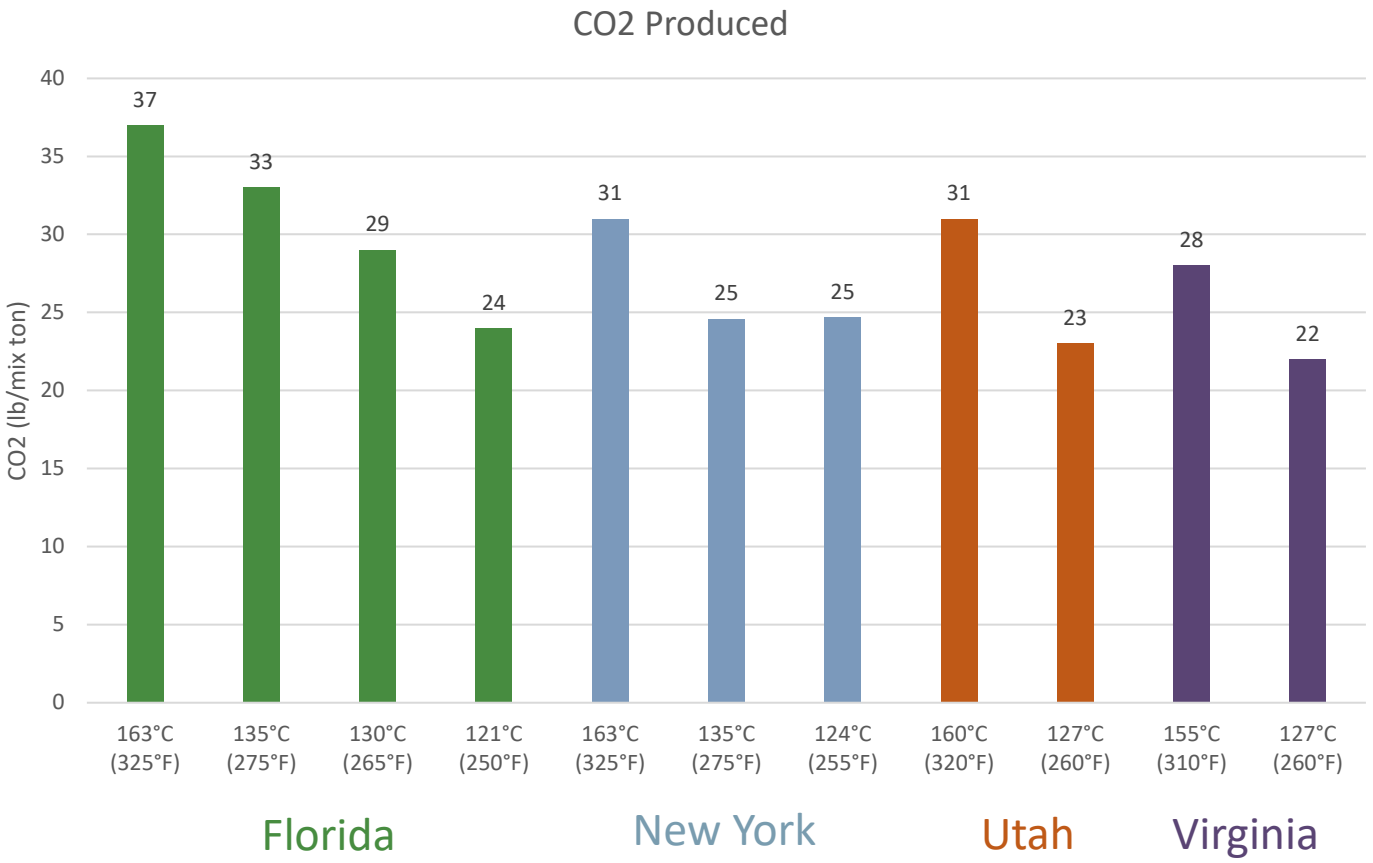


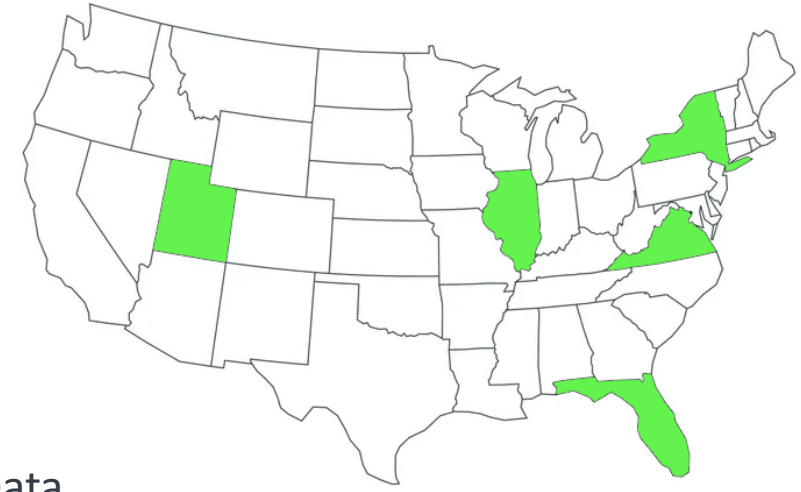
Illinois Contractor
- 300 Tons/hr
- Gencor Counter Flow
- 40% RAP Content
- 350k Mix Tons/yr
- $35k Savings (single plant at 275°F)

CO_2 Reduction 14.0%



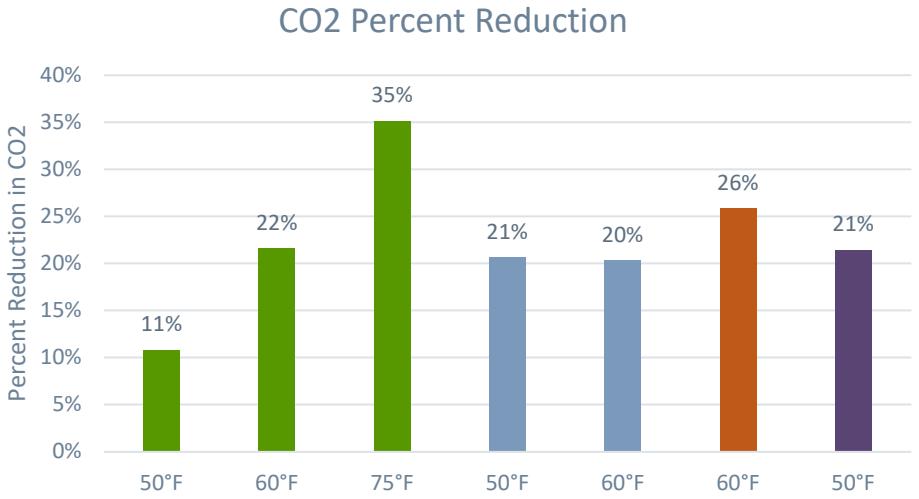
CO_2 Emissions – Stack Data





Average Data

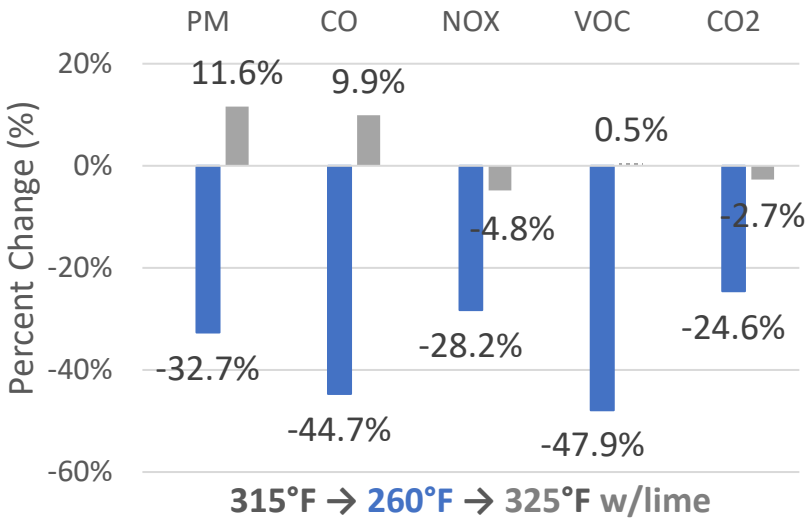
57.8°F Temperature Reduction
22.3% Reduction in CO_2



WMA Plant Stack Emissions Data

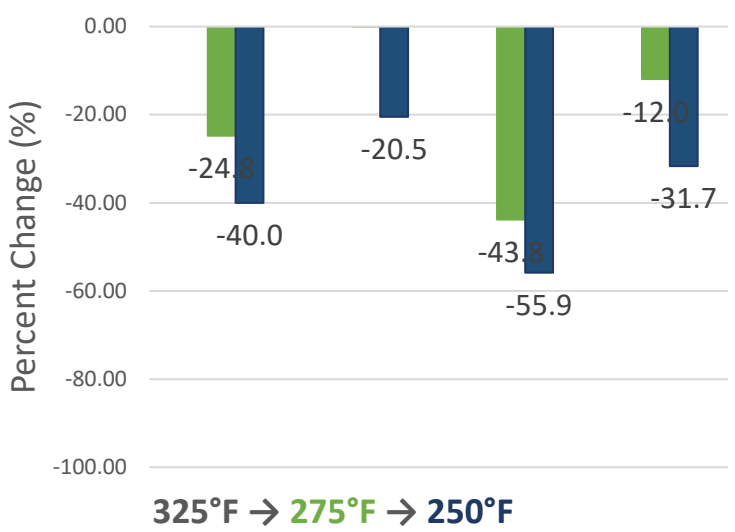
Input Data from Contractor **(Utah)**

- 360 Tons/hr run rate
- Gencor Counter Flow Drum
- 15% RAP Content



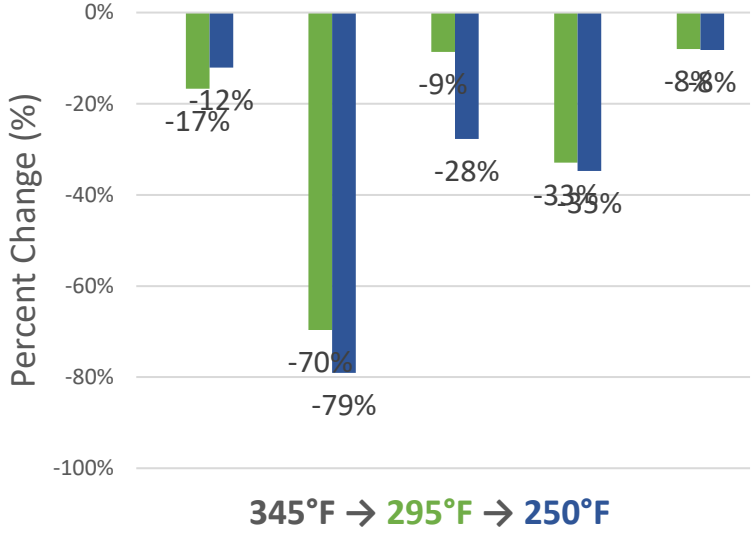
Input Data from Contractor **(Florida)**

- 200 Tons/hr run rate
- Astec Double Barrel Green
- 40% RAP Content

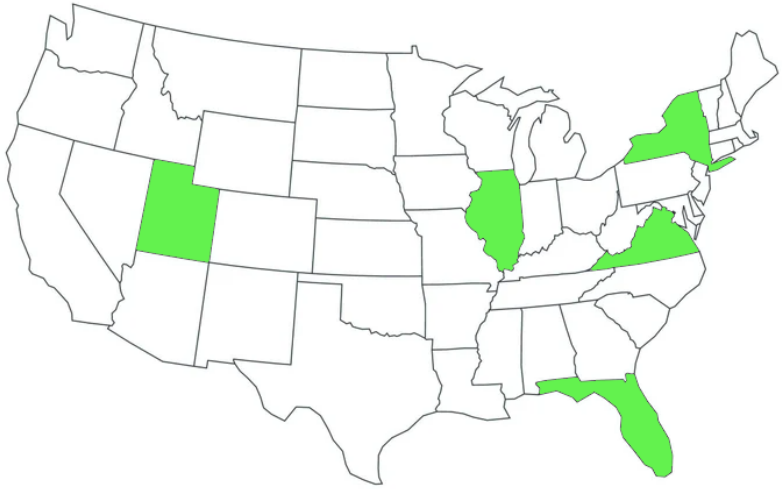


Input Data from Contractor **(Ohio)**

- 240 Tons/hr run rate
- Astec Double Barrel
- 20% RAP Content



Stack Data – CO_2 vs Fuel Data



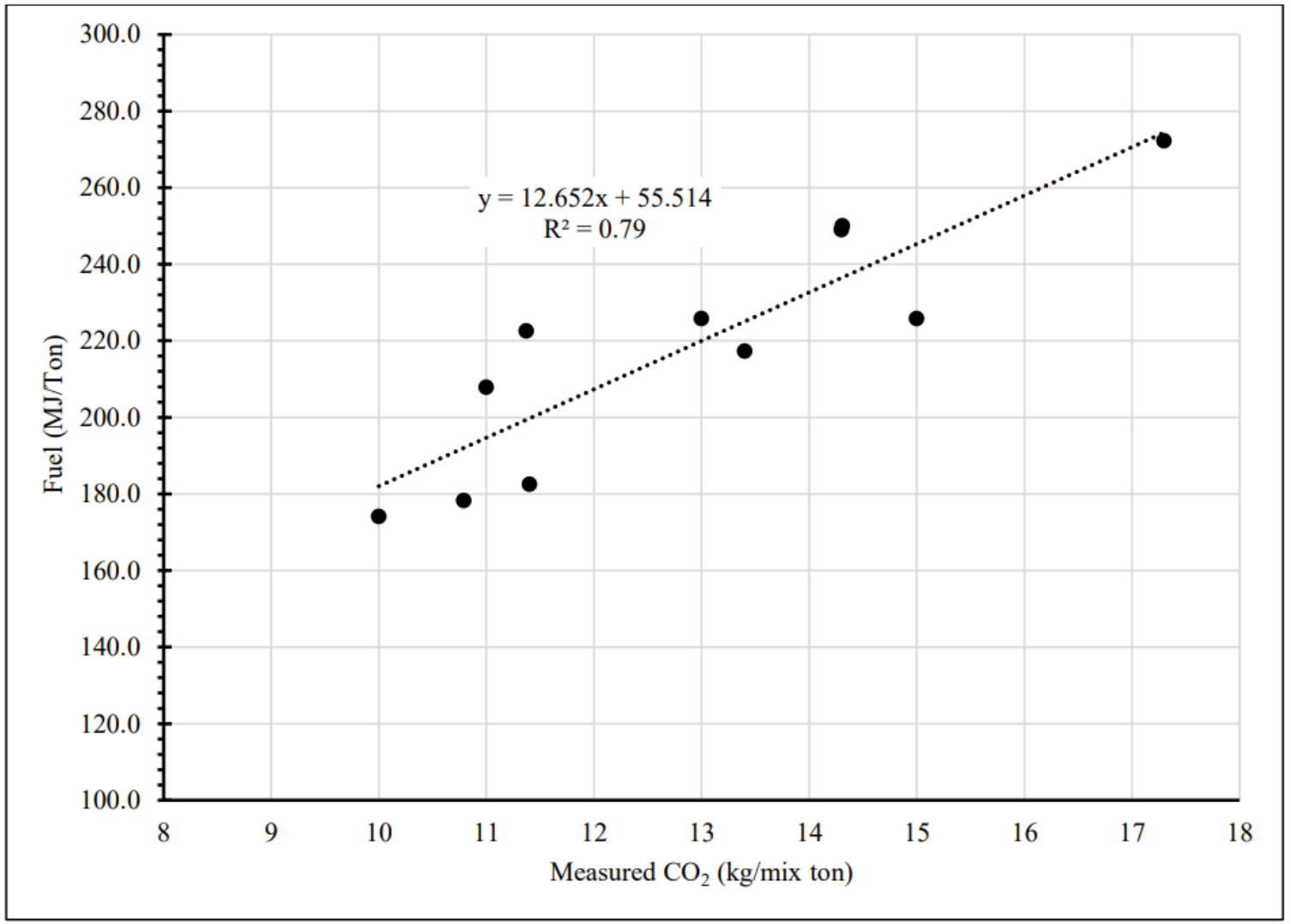
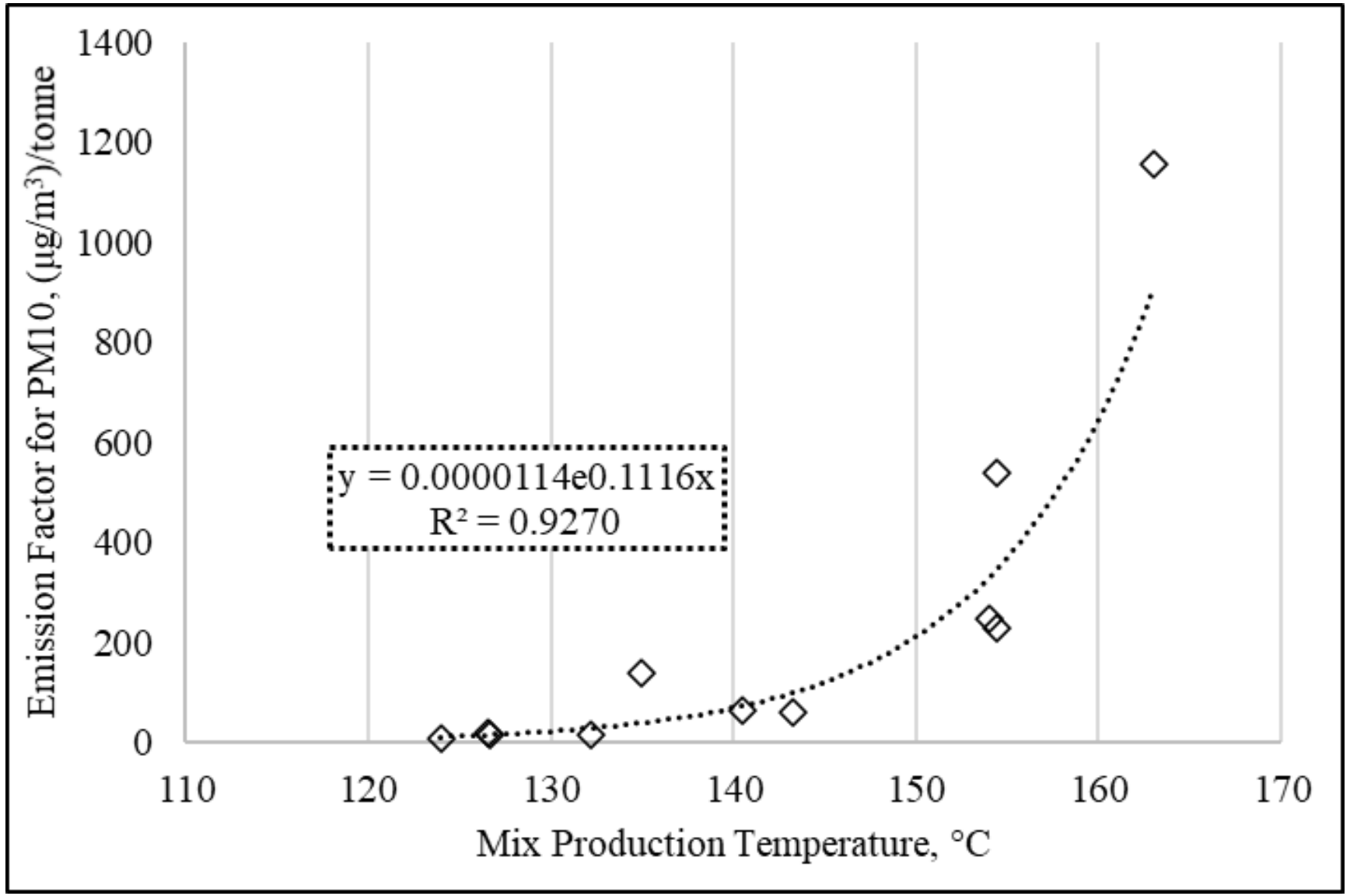
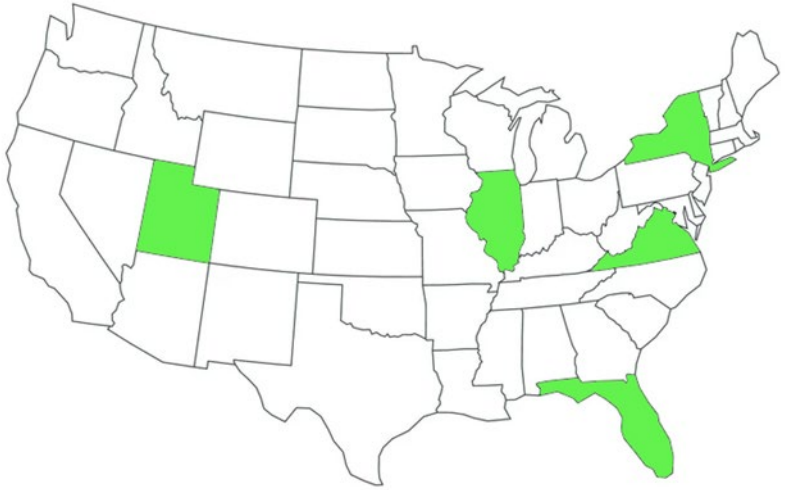


Figure 7. Correlation Between Fuel Consumption and CO_2 Emissions

Emission Factor Predictability



2022 Low Temperature WMA Data



Five Projects in Five States: “By the Numbers”

Temperature

55°F

Fuel

20%

CO_2

23%

Fugitive Emissions

Top of Silo (PM10)

92%

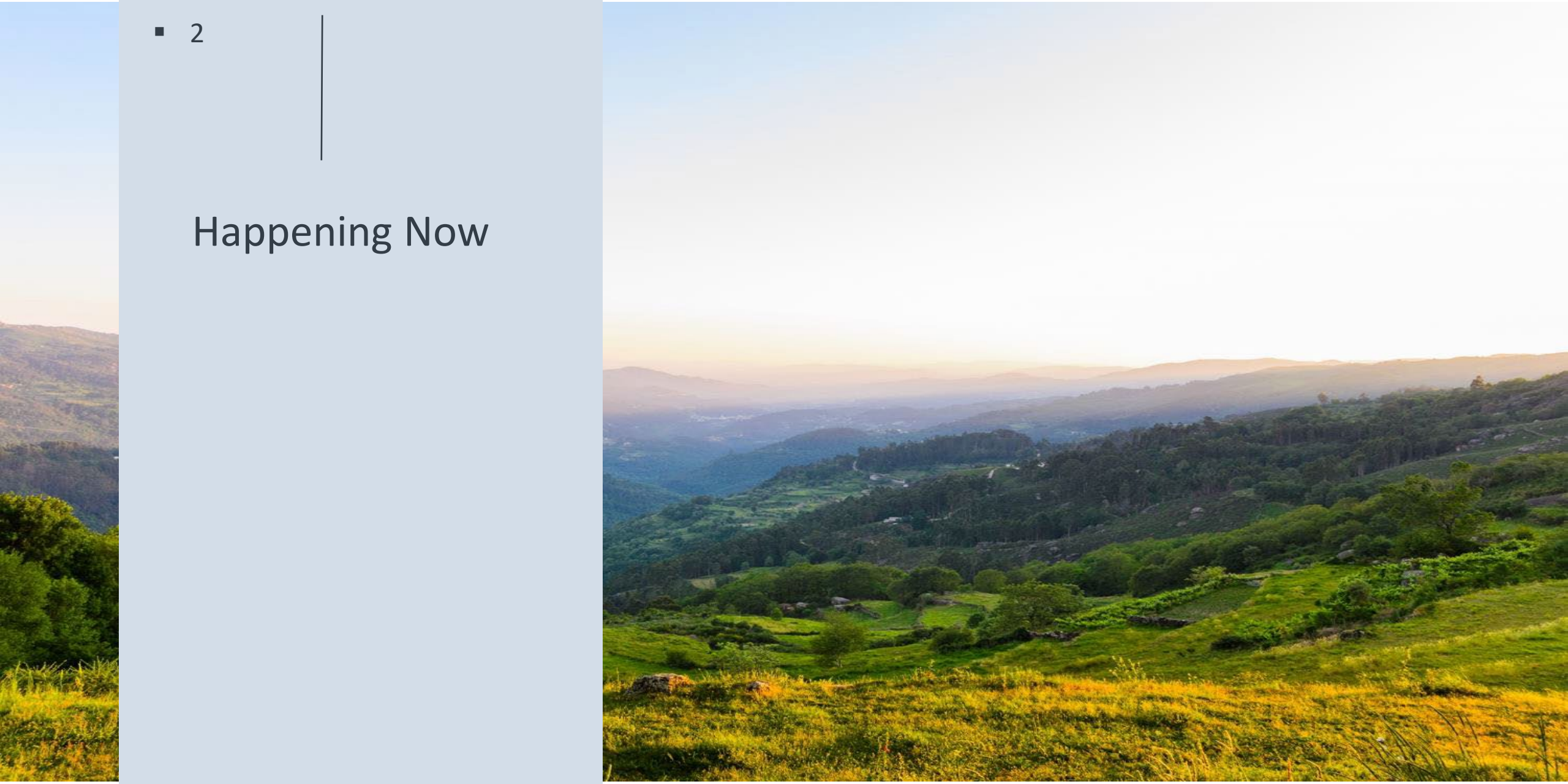
Note: Average Reduction across the projects

Conclusions

- PM10 concentration data showed that across the different sampling sites the average percent reduction in PM10 concentration was found to be 80 to 92 percent from an average WMA mixture temperature reduction of 30°C.
- PM2.5 concentration data showed that across the different sampling sites the average percent reduction in PM2.5 concentration was found to be 67 to 90 percent from an average WMA mixture temperature reduction of 30°C.
- CO_2 concentrations decreased on average 22.3 percent for the same WMA mixture production temperature reduction of 30°C.
- Burner fuel consumption decreased 20.4 percent for the same WMA mixture production temperature reduction of 30°C.
- Burner fuel reductions and stack CO_2 emissions correlated well (R^2 = 0.79) as temperature was reduced.
- Of the fifteen measuring sites for PM2.5 data in this study, all but one of the WMA measurements fell beneath the new German regulation in TRGS 900 [12].

- 2

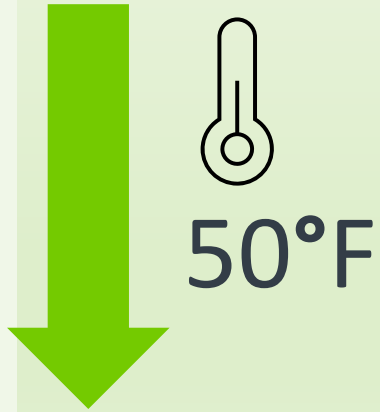
Happening Now



2023 Florida Contractor - WMA Data

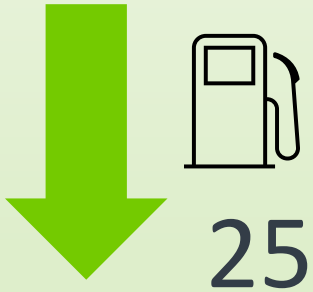
Contractor Implementation in Florida
120,000 mix tons August 2023 to date -> 200,000 target 2023
50% Private work
40% RAP non-PMA, 20% in PMA

Temperature



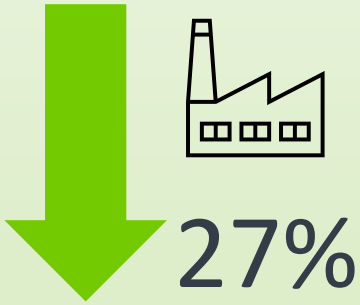
50°F

Fuel



25%

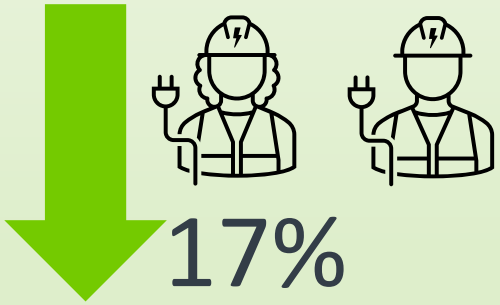
CO2



27%

Silos/Dryer

(Electrical) kwh



17%

Note: Average Reduction across the projects

Florida Contractor Trial

- Plant Burner/Dryer kWh
  - Average kWh/ton - Hot mix: 43 / Average kWh/ton - Warm mix: 36
  - 17% reduction
- Burner CO2 - eCO2/tons
  - Hot mix: 8.2 kg / Warm mix: 6 kg
  - 27% reduction
- Fuel - Therms/Hour
  - Hot mix: 44 therms/hour / Warm mix: 33 therms/hour
  - 25% reduction

Questions