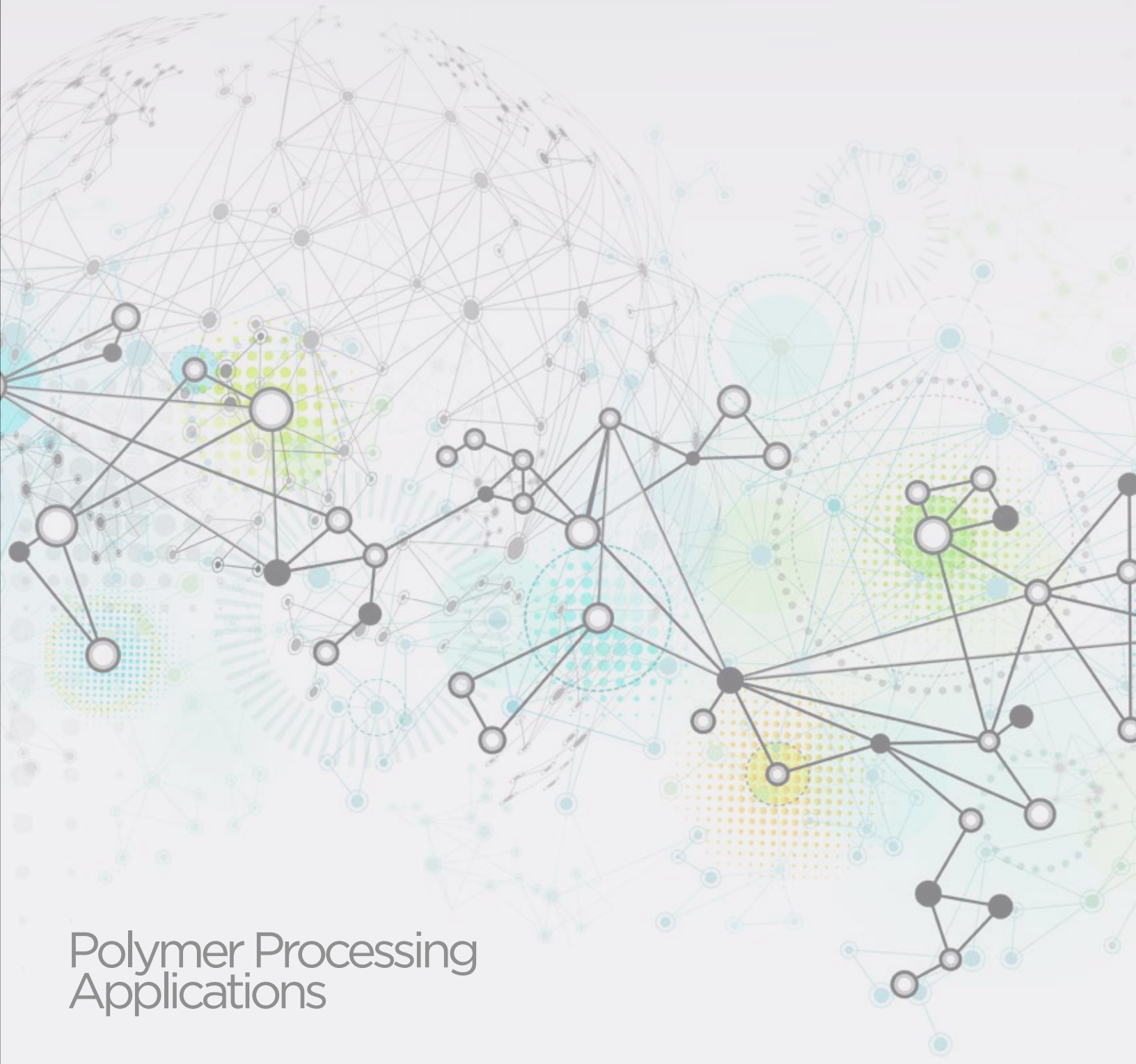
CERANOVUS®
PRODUCTS



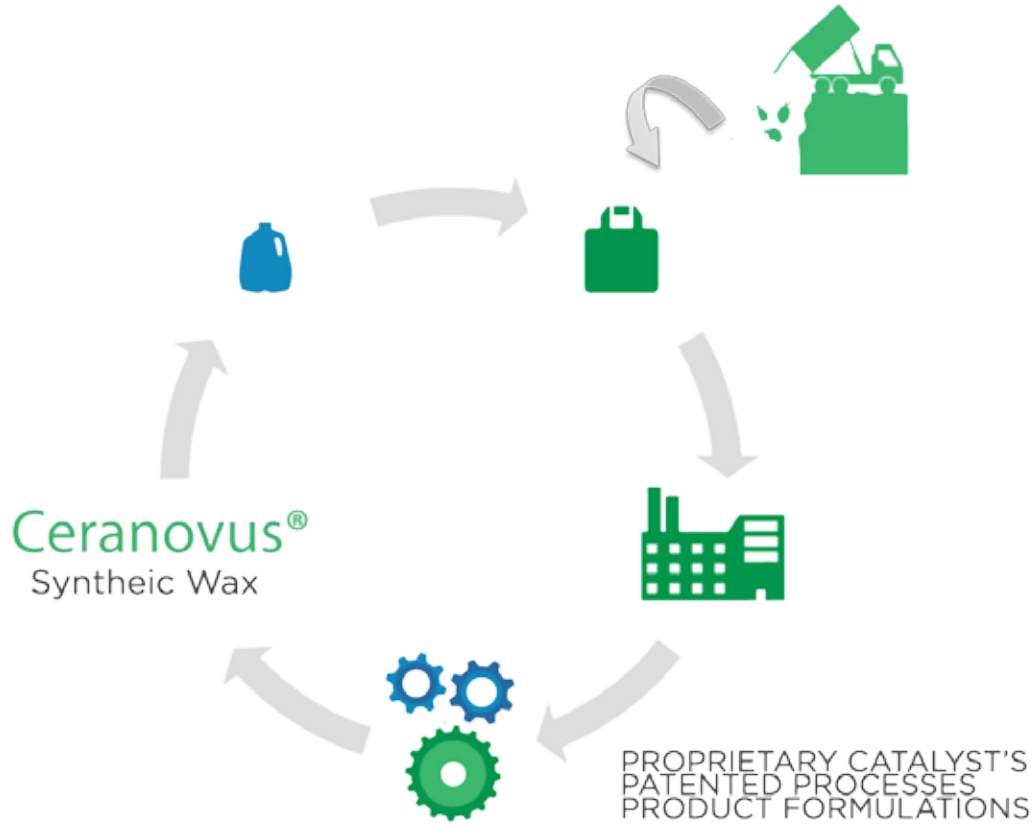
Polymer Processing Applications

GreenMantra® Ceranovus® Synthetic Additives—Cost-Effective Performance and Process Enhancement for Various Plastic Processing Applications

Through our proprietary technology and patented process, we produce a wide range of high quality performance additives designed for masterbatch, composite, PVC, polyethylene, and polypropylene plastic processing. These non-polar polyolefin waxes, when used in various plastic processing application, will significantly improve line speed without affecting the tensile properties of the resin. Our synthetic additives also improve pigment and filler dispersions, producing uniform color and enhanced distribution of components.

Third-party laboratory testing and subsequent large-scale commercial case studies have proven benefits including energy savings, increased production throughput, reduced backpressure (for reduced equipment wear) and lower overall cost of plastics production. Furthermore, Ceranovus® brand additives blend uniformly with various plastics feedstock, increasing melt flow, percentage elongation, and product strength in the final pellet or formed product.

These specially designed products have a positive impact on performance and are sustainably made with 100% recycled plastics.



WORKING TOWARD A

CLEANER ENVIRONMENT

Of the **300 million tons** of plastic produced globally each year, only about 10 percent is recycled. We are committed to the cost-effective transformation of plastic waste into high value products, improving the environment and creating a more circular economy for plastics.

Furthermore, sourcing feedstocks from recycled plastic materials means GreenMantra's products lessen the challenges associated with petroleum-based products, such as constrained supply and cost volatility.

Third party testing confirms energy savings and throughput benefits

Fig: 1: Natural post-consumer HDPE bottle flake

To determine the performance characteristics of the new Ceranovus additive products, GreenMantra engaged Plastics Forming Enterprises, LLC, an independent plastics consulting, research and engineering firm, to conduct testing. After initial laboratory tests suggested the new additives were likely to succeed in achieving desirable plastics processing benefits, Plastics Forming Enterprises initiated a commercial-scale study, with technical assistance from extrusion manufacturer Starlinger. The goal was to assess how the addition of GreenMantra's Ceranovus A120 additive would impact processing the resulting plastic and final formed product.

The A120 additive was blended with post-consumer recycled (PCR) high-density polyethylene (HDPE) natural bottle flake—a common recycling feedstock—and processed on typical Starlinger commercial extrusion equipment. The resultant reprocessed pellet and subsequent injection-molded or extrusion-blown products were then evaluated.

For the trial runs, the test material was introduced to the flake blend at the screw. Temperature was maintained at 248-250°C throughout. Back pressures, energy usage, screw speed and pounds of product per hour were recorded. Differences in pressure, energy usage and throughput were calculated, relative to the control with no additive present. Melt flow properties of the resultant pellet were measured with a melt rheometer.

The first trial compared the performance of HDPE flake with 0% (control), 2% and 4% A120 in a steady-state extrusion at a constant screw speed of 125 RPM. Results are shown in Table 1. Addition of the performance additive increased melt flow by 30-40% in the final pellet. With the unchanged screw speed, throughput was essentially constant. However, adding the A120 had a significant beneficial effect on back pressure, which decreased up to 11%, correlating to less wear and tear on equipment. In addition, the resultant decrease in back pressure resulted in a decrease in energy usage of 15-20%, which could be expected to reduce energy costs.

Table 1: Recycled plastic processing effects of adding Ceranovus A120 to PCR HDPE. Trials ran 3 hours at constant temperature to allow for stabilization. In this phase of the test, screw speed was held constant while A120 was added at 2 to 4% with respect to the flake at around 290 lbs/hr. Note the relative increased melt flow, decreased backpressure and decrease in kilowatt usage and cost per pound.

% Ceranovus A120 & screw RPM	0% Control 125 RPM	2% Test 125 RPM	4% Test 125 RPM
Temperature (°F)	249	250	250
Fractional Melt Flow	0.47	0.62	0.67
Melt Flow (% rel. to control)	N/A	32%	42%
Average Pressure (PSI)	1769	1595	1566
Pressure (% rel to control)	N/A	-10%	-11%
Average Energy Usage (kW/hr)	68.5	54.7	58.9
Energy Usage (% rel. to Control)	N/A	-20%	-14%
Average Throughput (% rel. to Control)	289	293	285
Throughput (% rel to Control)	N/A	1.4%	-1.0%
Energy Use per Pound (kW/lb)	0.237	0.187	0.207
Cost Change (% rel to Control)	N/A	-21%	-13%

In the second set of trial runs, test material was fed at a rate that would stabilize the extruder at the same average back pressure as the control run—i.e. around 122 bars. Results are shown in Table 2. Maintaining a set pressure kept the energy usage near constant. In this case, however, the ability to increase screw speeds allowed for a significant increase in throughput—up to 28%.

Fig 2: Natural HDPE flake reprocessed to pellet using Ceranovus A120 additive

Table 2: Recycled plastic processing effects of adding Ceranovus additives to PCR HDPE. In this phase of the test, backpressure was held essentially constant while % of Ceranovus A120 additive was increased. Note the relative increases in melt flow and throughput, and the decrease in energy cost.

% Ceranovus A120 & Screw RPM	0% Control 125 RPM	2% Test 165 RPM	4% Test 170 RPM
Temperature (°F)	249	248	248
Melt Flow Index	0.47	0.63	0.63
Melt Flow (% rel. to Control)	N/A	34%	34%
Average Pressure (PSI)	1769	1827	1798
Pressure (% rel. to Control)	N/A	3.3%	1.6%
Average Energy Usage (kW/hr)	68.5	72.4	70.3
Energy Usage (% rel. to Control)	N/A	5.7%	2.6%
Average Throughput (lbs/hr)	289	366	370
Throughput (rel. to Control)	N/A	27%	28%
Energy Use per Pound (kW/lb)	0.237	0.198	0.198
Cost Change (% rel. to Control)	N/A	-16%	-20%

Overall, energy, pressure and throughput enjoyed a direct benefit from the addition of the performance additive. When processing at a constant screw speed, adding the A120 resulted in an energy benefit, reduction in equipment wear, and an increase in melt flow. Higher speed processing with the same approximate energy consumption achieved an output benefit and maintained the same increase in melt flow. Of note, maintaining, as opposed to increasing RPM processing speeds, may offer an advantage in that the material and additive have more time to blend with increased residence time in the screw.

Further testing demonstrates performance benefits for pellets and parts

Processing gains are beneficial only if the quality of the end-product is maintained. To determine the impact of the Ceranovus additives on end-products such as injection molded parts and extrusion blown bottles, parts and bottles made with 2% and 4% of the additive were evaluated.

The injection molded parts test data is shown in Table 3. Melt flow rates have increased in parts containing A120 compared to the control, as seen with pellet samples. This is an expected result due to the external lubrication of the additive, which reduces the degree of cross linkage occurring at the interface between the polymer and barrel or mold. The plastic continuing 0%, 2% and 4% A120 samples exhibit similar moisture levels and densities. Izod impact testing, flex modulus and tensile strength also show comparable results, with slight improvements in each parameter compared to the control. The percentage elongation for the sample containing 2% A120 registers a 19% increase and, for the 4% sample, a 62% increase over the control. It is suspected that this improvement is related to the internal lubrication and blending of the A120 additive with the polymer matrix. Overall, these results demonstrate the beneficial effect of adding the Ceranovus A120 performance additive, for the extrusion of plastic parts.

Table 3: Injection molded parts test data for pellets and bottles with 0%, 2% and 4% Ceranovus A120 wax content.

% A120	0%	2%	4%
Pellet Melt Flow Rate	0.4	0.63	0.63
Part Melt Flow	0.38	0.53	0.53
Volatile (%)A120	0.008	0.008	0.008
Density	0.949	0.94	0.949
Izod (lbf-ft-in)	10.20	11.44	10.20
Flexural Modulus (PSI)	164447	168343	166538
Tensile @ Yield	3805	3921	3921
Elongatation Average	374%	444%	607%
% Elongation Increase (re.to Control)	N/A	19%	62%

Fig 3: Blow moded bottle produced from pellet reprocessed with Ceranovus A120 additive

Extrusion blow-molded bottles were made with reprocessed pellets containing 0%, 2% and 4% A120, under identical process conditions. The experimental bottles were drop-tested. Results are shown in Table 4 and demonstrate a reduction in breaks/failures by 50% and 100% in the bottles containing 2% and 4% A120, respectively.

Table 4: Bottle drop test results for bottles with 0%, 2% and 4% Ceranovus A120 content

0% Wax Content (Control)																				
Height (FT)	Bottle Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	X																			
6		X																		
7			X																	
8				X																
9					X															
10						X														
11							X						X		X					
12								X	X	X	X	B		B		X	X	X	X	X

Note: # 12 break at bottle thread, #15 break at base seam pin hold

2% Wax Content Ceranovus A120																				
Height (FT)	Bottle Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	X																			
6		X																		
7			X																	
8				X																
9					X															
10						X														
11							X				X									
12								X	X	B		X	X	X	X	X	X	X	X	X

Note: # 10 break base corner slit

4% Wax Content Ceranovus A120																				
Height (FT)	Bottle Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	X																			
6		X																		
7			X																	
8				X																
9					X															
10						X														
11							X													
12								X	X	X	X	X	X	X	X	X	X	X	X	X

Note: No breaks

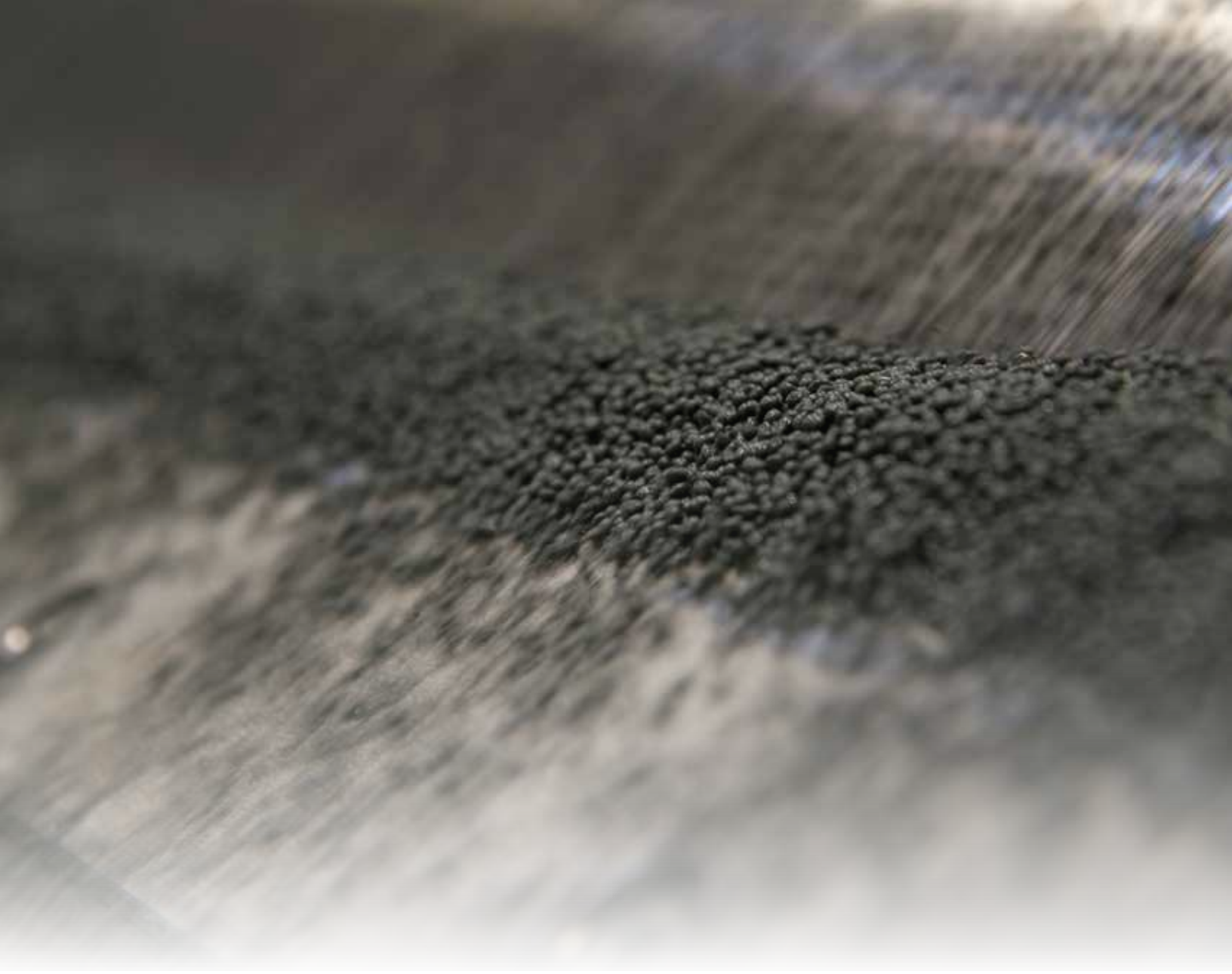
Summary

GreenMantra Technologies offers several avenues whereby plastics processors can benefit from this novel additive to impact both product margin and performance. Potential benefits include:

- Decrease process backpressure, and equipment wear
- Reduce energy consumption related to extrusion by >10%
- Achieve as much as a 30% increase in throughput
- 30 - 40% increase in plastic melt flow
- 20 - 60% increase in plastic percentage elongation
- 50 - 100% fewer breaks/failures in product forming

Through the addition of this additive directly at the extruder, or in earlier blending/storage silos, our Ceranovus A120 product provides a simple path to both process and performance gains.

Our skilled team of application scientists are here to assist with any testing, formulation development, or in the field assistance to help drive value, performance, and sustainability for our customers.



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greenmantra.com
or email
info@greenmantra.com

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